Living with a Star: Opportunities for Geospace Science

Agenda:

- LWS Program Overview
- Geospace Science Objectives & Priorities
- Geospace Flight Elements
- The Broader Geospace Project, Opportunities for Participation
- Comments, Questions & Answers

Goals of this Town Hall Meeting

- Present the recommendations of the Living with a Star (LWS) Geospace Mission Definition Team (GMDT)
  - scope of the science
  - recommended mission set
  - closure through modeling
  - inter-disciplinary science, science to operations
- Introduce participation opportunities
  - flight opportunities
  - interdisciplinary scientists
  - current and future NASA Research Announcements (NRAs)
  - collaborations with other national and international programs
- Solicit community comments
  - during comment/Q&A period of this meeting
  - by later communication with LWS program or project offices

LWS Program and LWS Geospace Program Personnel

Richard Fisher
Sun-Earth Connection Division Director

Madhulika “Lika” Guhathakurta
LWS Program Scientist

Arthur Poland
LWS Project Scientist

Larry Zanetti
LWS Project Scientist at JHU/APL

LWS Program and LWS Geospace Program Personnel

Barbara Giles
LWS Geospace Project Scientist

Barry Mauk
LWS Geospace Mission Scientist at JHU/APL

Nicola Fox
LWS Geospace Study Scientist at JHU/APL

Robert Lebair
LWS Geospace Formulation Manager

Living with a Star Program Overview

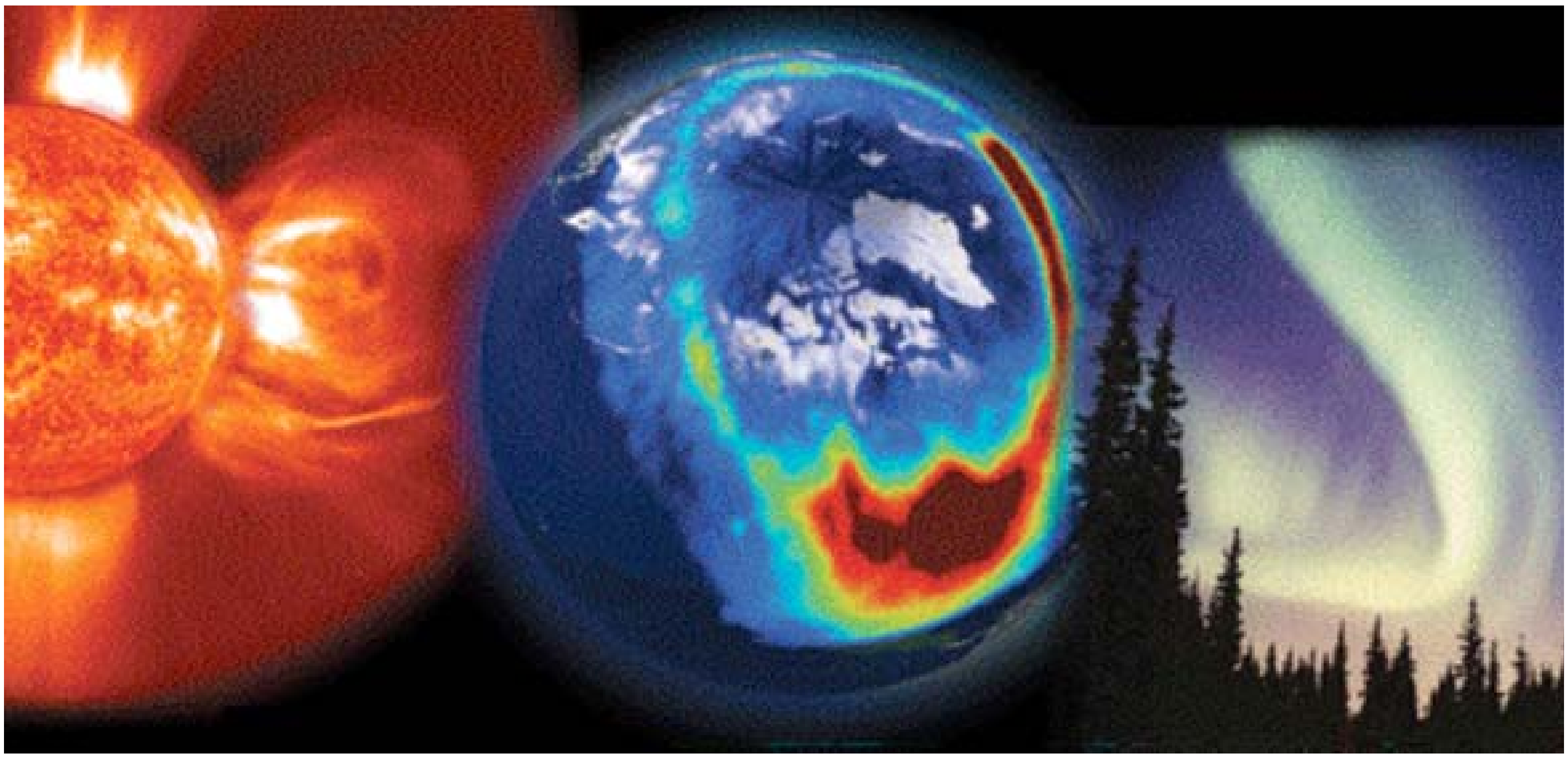
Dr. Richard Fisher

Sun-Earth Connection Division Director

NASA Headquarters

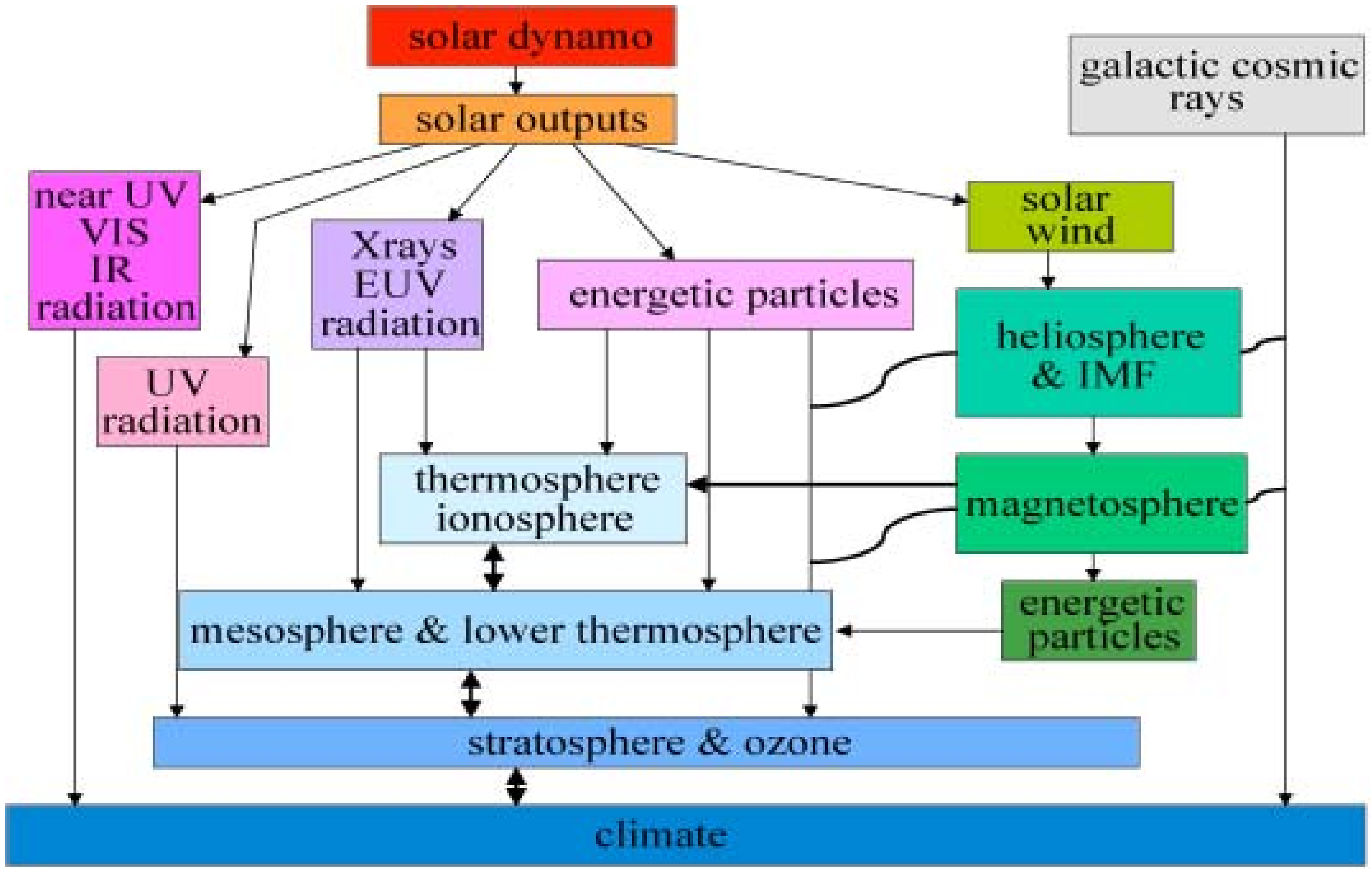
LWS Missions Goal

Develop the scientific understanding necessary to effectively address those aspects of the connected Sun Earth system that directly affect life and society.



LWS is a Systems Approach

LWS focuses not on any one region of space, but rather on our Sun Earth Region as one system.



A very important part is the study of the connection between the regions and how one drives a response in another.

LWS and STP within the NASA Sun-Earth Connections Theme

Both are:

- ongoing, continuous sequences of SEC community defined strategic projects;
- included as strategic elements within the Sun-Earth Connection Science Roadmap.

They differ in that:

- Solar Terrestrial Probes (STP) utilize the systems approach to develop the curiosity-driven scientific understanding necessary to address the critical physics behind the Sun-Earth connected system and its interaction with the entire solar system.
- Living with a Star (LWS) utilizes the systems approach to develop the scientific understanding necessary to address those aspects of the Sun-Earth connected system that directly affect life and society.

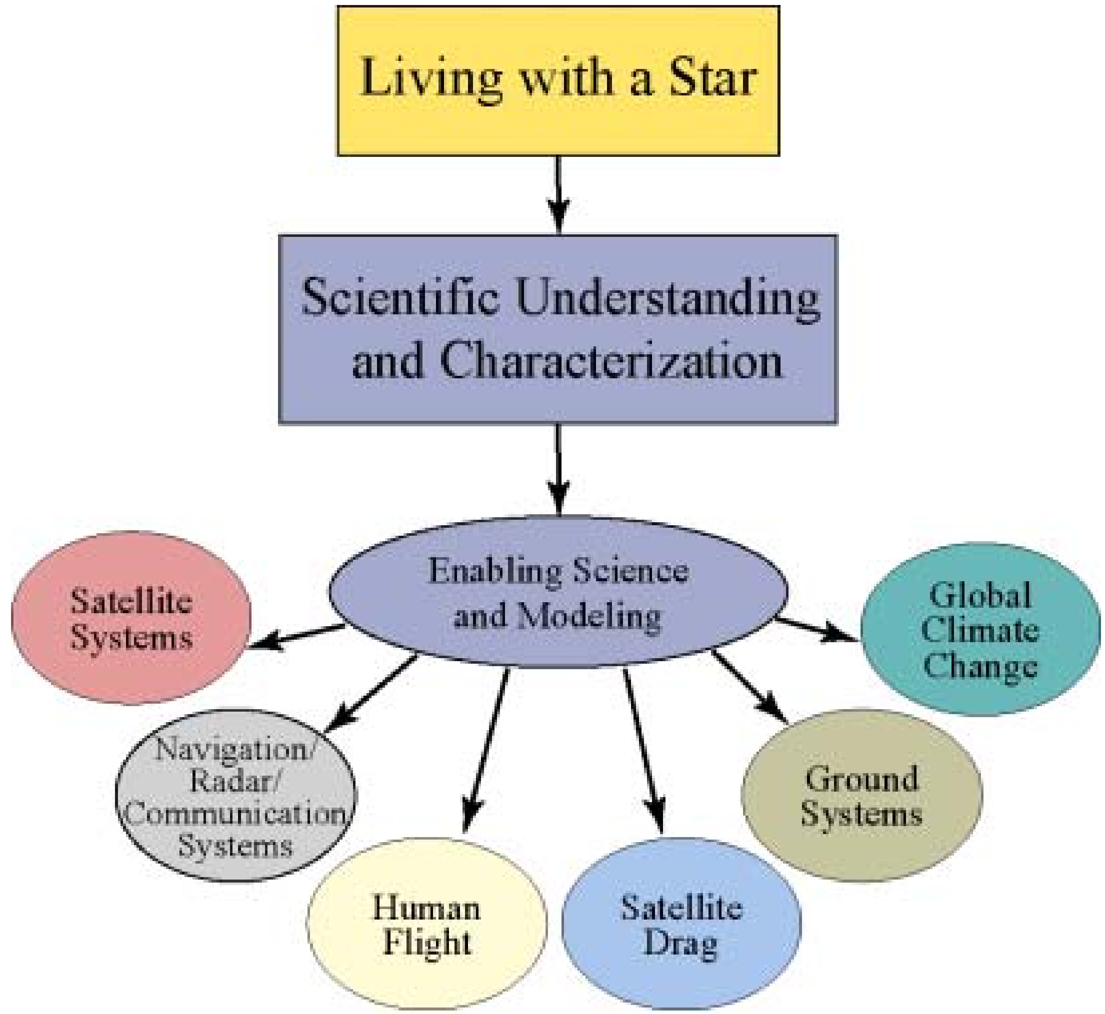
LWS is not:

- a space weather operations or space weather monitoring program.

Science Application as the Focus

The main goal of the LWS Program is to understand ***"how solar variability affects humans and technology"***

LWS will perform basic science research, leading to further understanding, which in turn will be adapted to operations to improve nowcasting and forecasting.



Scope of the LWS Program

The initial LWS strategic program elements are:

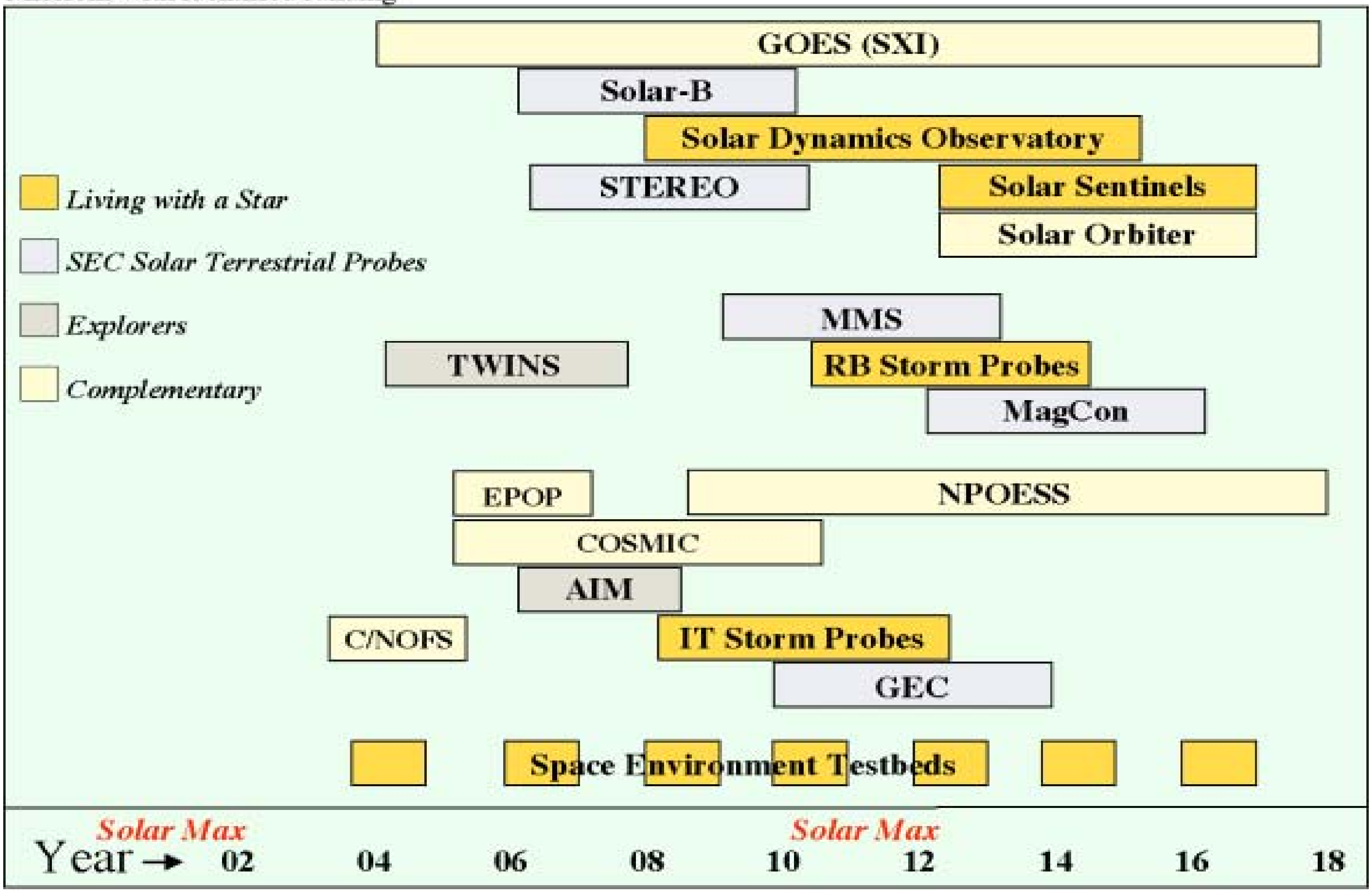
- Solar Dynamics Observatory (SDO)
- Solar Sentinels
- Space Environment Testbeds
- Targeted Research and Technology (TR&T)
- Data Systems Development

  and

- **The Geospace Missions Network**

Program Schedule

Missions with identified funding



LWS/Geospace Missions Network

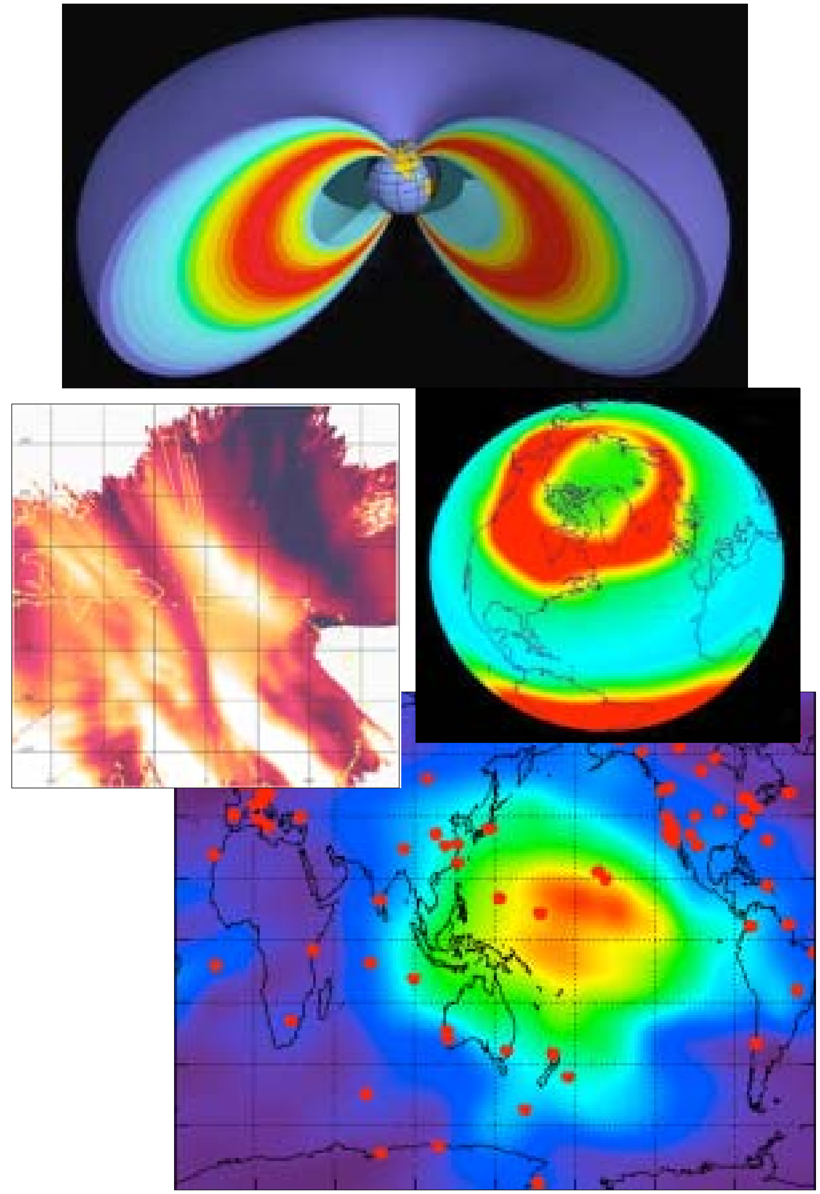
Goal: Understanding and characterizing those geospace phenomena that most affect life and society.

Status: The Geospace Missions Definition Team has completed its work and defined a program with four components:

- The Geospace Missions Network
- Missions of Opportunity
- Leveraged Programs
- Instrument Development Program

Pre-mission concept development is underway at NASA/GSFC and JHU/APL.

Geospace Definition Team Report available at:
http://lws.gsfc.nasa.gov



LWS/Geospace Project Formulation

LWS Geospace Study Scientist: Robert Hoffman
Mission Definition Team, chaired by Paul Kintner
GMDT Report published, September, 2002

Not pictured: Rod Heelis, Bob Schunk, and Michael Golightly

LWS Geospace Science Objectives and Priorities

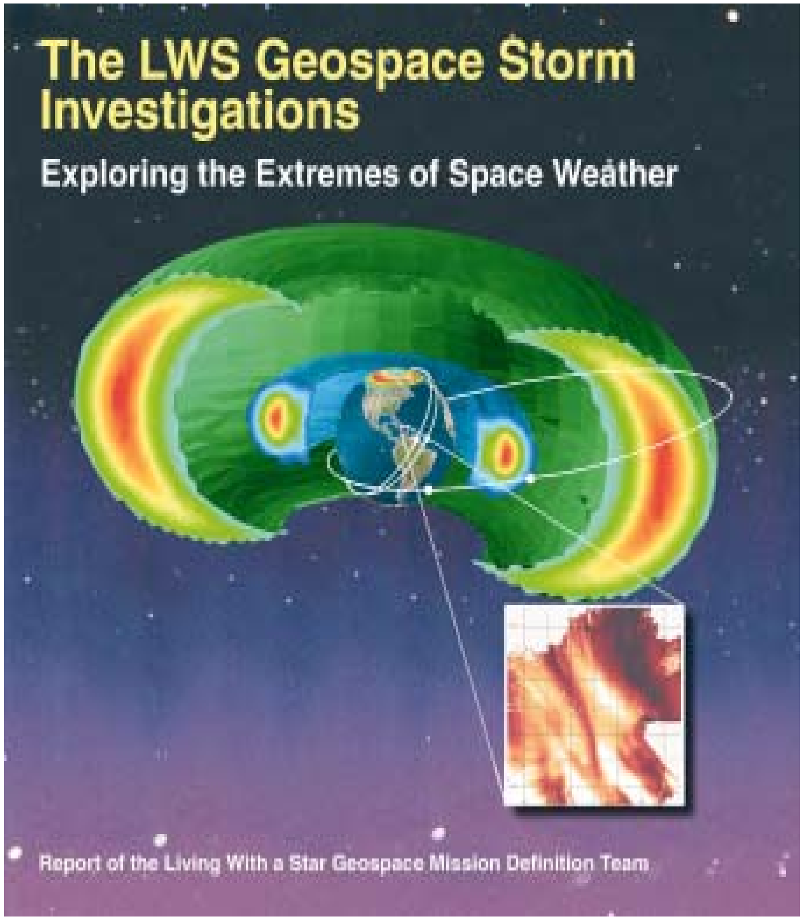
Dr. Paul Kinter

Chair, LWS Geospace Missions Definition Team

Cornell University

Geospace Mission Definition Team

- Committee of 18 scientists and user community representatives chartered to:
  - Review and apply to geospace the science and user objectives from the LWS/Science Architecture Team.
  - Derive and prioritize measurement requirements from the science and user objectives.
  - Develop and prioritize the set of flight elements.
- Prepare a geospace implementation plan with explicit priorities.



Report released September, 2002
http://lws.gsfc.nasa.gov/geospace/

Geospace Science Priorities

1: Acceleration, global distribution, and variability of **energetic electrons and ions in the inner magnetosphere**.

2A: Global-scale behavior of the **ionospheric electron density**.

2B: Small scale **ionospheric density irregularities**

3A: Improved **specification of the neutral density** in the thermosphere.

3B: **Distribution of electric currents** connecting the magnetosphere to the ionosphere.

4: Relationship between very energetic electron and ion **fluxes in the interplanetary medium and their fluxes at low altitude**

5: Geospace drivers that potentially affect **ozone and climate**.

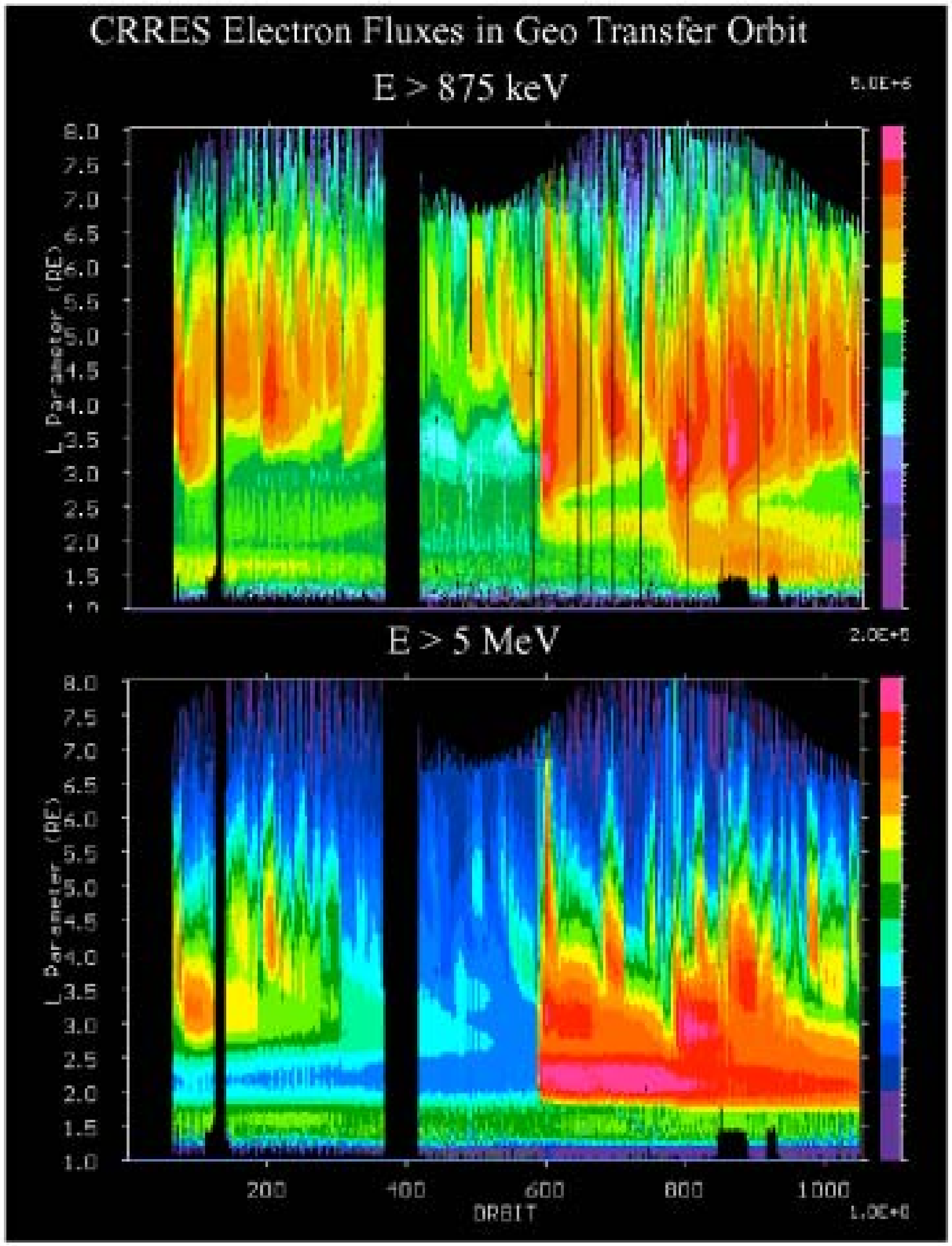
Based on a Convolution of Importance and Potential for Progress

LWS/Space Weather Effect		
Satellite Systems	Monitor and predict energetic electron and ion exposure	A
Nav/Com Systems	Understand and characterize spatial distribution of electron density in the ionosphere	B
Human Flight	Monitor and predict energetic electron and ion exposure on astronauts and of flight crews	C
Satellite Drag	Understand and characterize neutral density distribution	D
Ground Systems	Understand how enhanced ionospheric currents induce currents in ground-level conductors	E
Global Climate Change	Characterize affect of solar variability on ozone and near-surface temperature change	F

	LWS/Geospace General Objective:
A, C	***Priority 1:*** Understand the acceleration, global distribution, and variability of energetic electrons and ions in the inner magnetosphere.
B, E	**Priority 2A:** Determine the effects of long and short term variability of the Sun on the global-scale behavior of the ionospheric electron density.
B	**Priority 2B:** Determine the solar and geospace causes of small scale ionospheric density irregularities in the 100 km to 1000 altitude range.
C, D	**Priority 3A:** Determine the effects of solar and geospace variability on the atmosphere enabling an improved specification of the neutral density in the thermosphere.
B, D, E	**Priority 3B:** Understand how solar variability and the geospace response determine the distribution of electric currents that connect the magnetosphere to the ionosphere.
A, B, C, F	**Priority 4:** Determine the quantitative relationship between very energetic electron and ion fluxes in the interplanetary medium and their fluxes at low altitude, particularly the geomagnetic cut-offs.
F	**Priority 5:** Quantify the geospace drivers that potentially affect ozone and climate.

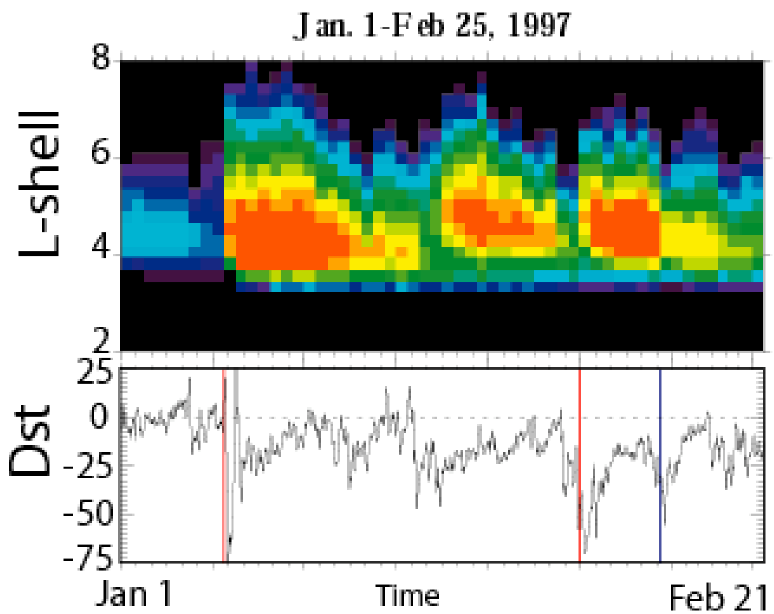
Geospace Science Priority 1

- Understand the acceleration, global distribution, and variability of energetic electrons and ions in the inner magnetosphere.
  - Which physical processes produce radiation enhancement event?
  - What processes are responsible for radial transport and acceleration?
  - Do localized acceleration processes contribute significantly to radiation belt acceleration?
  - How do we distinguish among competing or simultaneous acceleration and transport events?
  - How do we predict and model the spatial, spectral, and temporal characteristics of radiation belt enhancements?



Sudden creation of radiation belts - acceleration is not diffusive!

Not All Storms Produce Radiation Belts

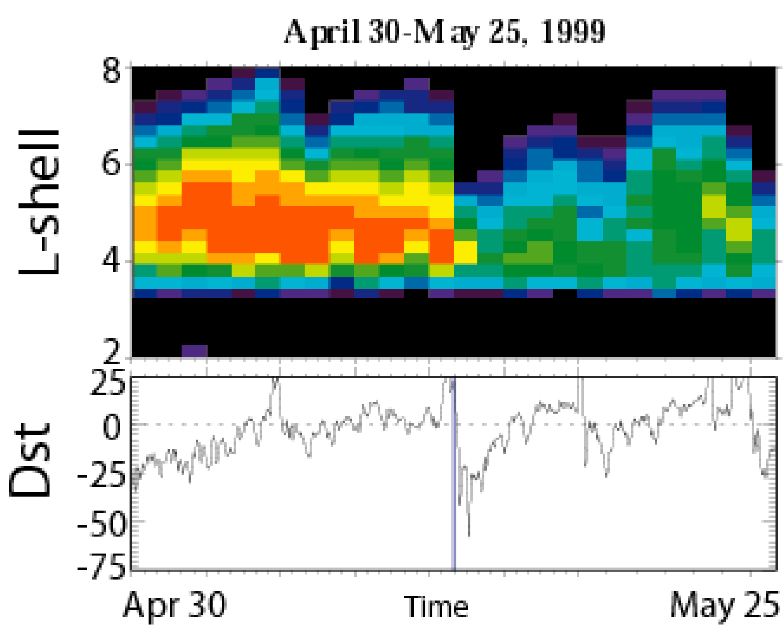


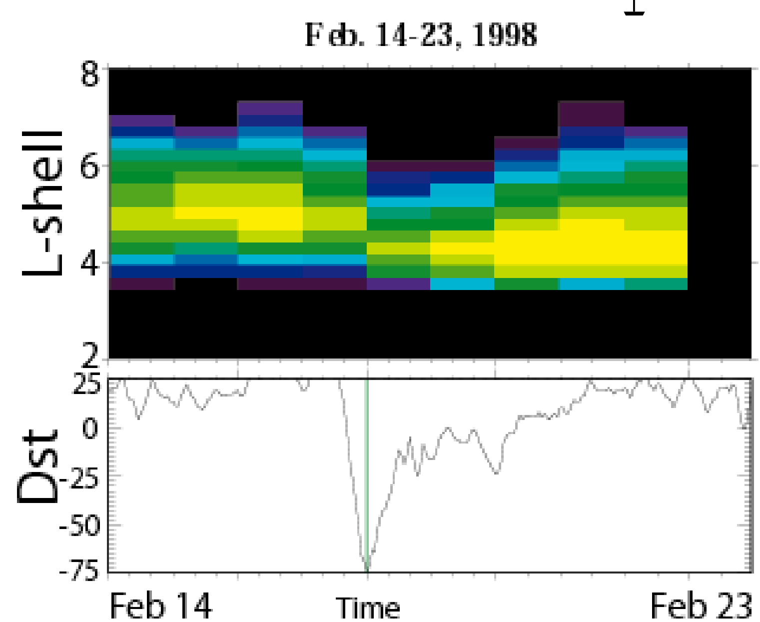
MORE

Polar HIST 1.2-2.4 MeV

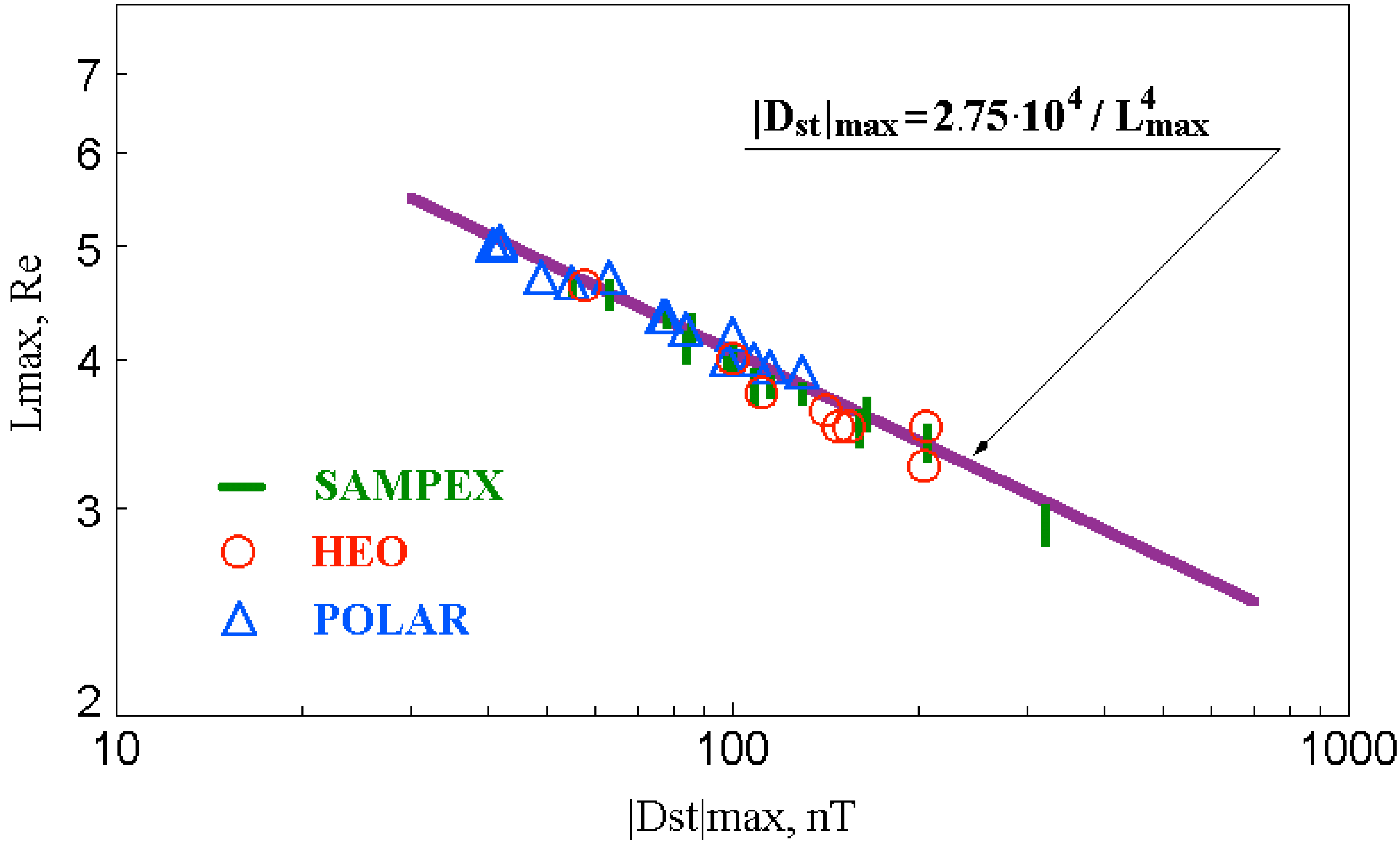
SAME INTENSITY

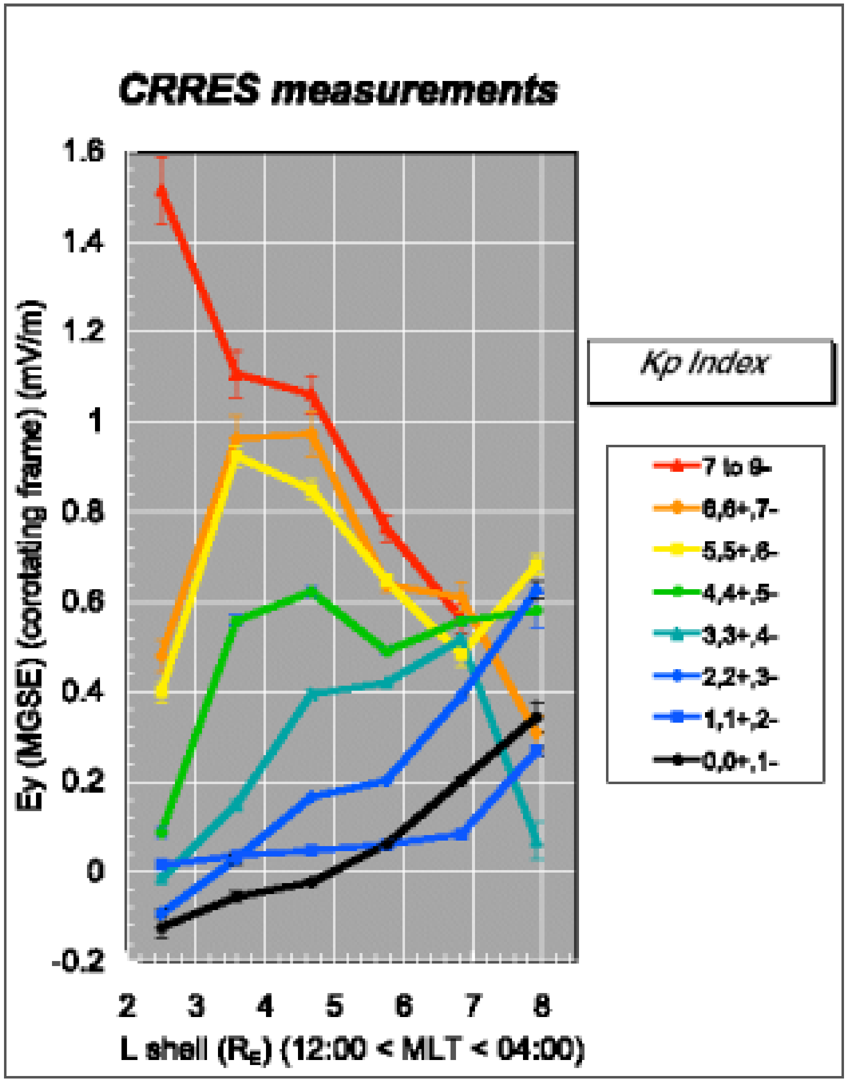
LESS

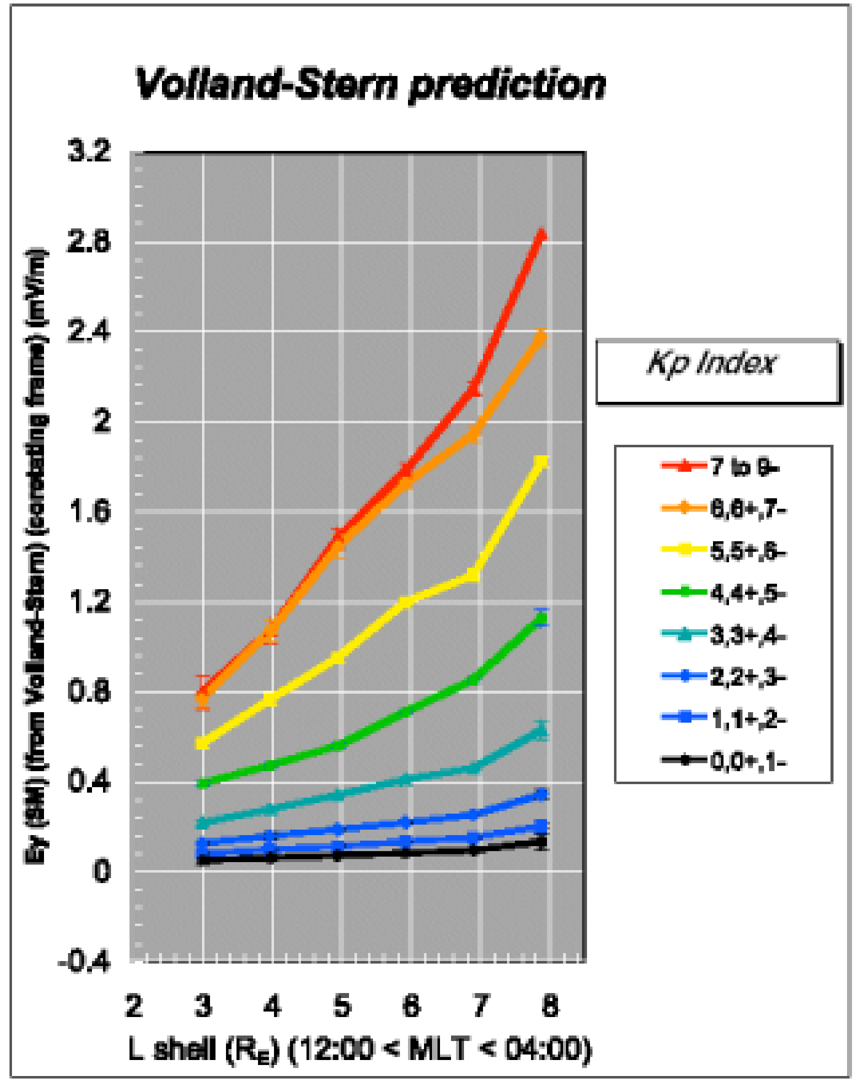




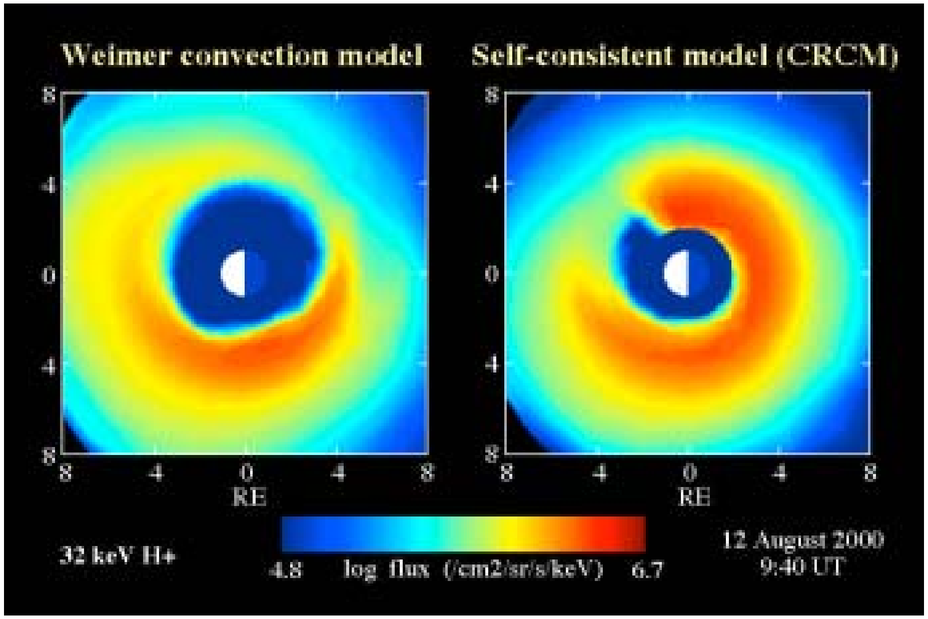
Relationship Between 2MeV Electron Peak Flux Location and Dst







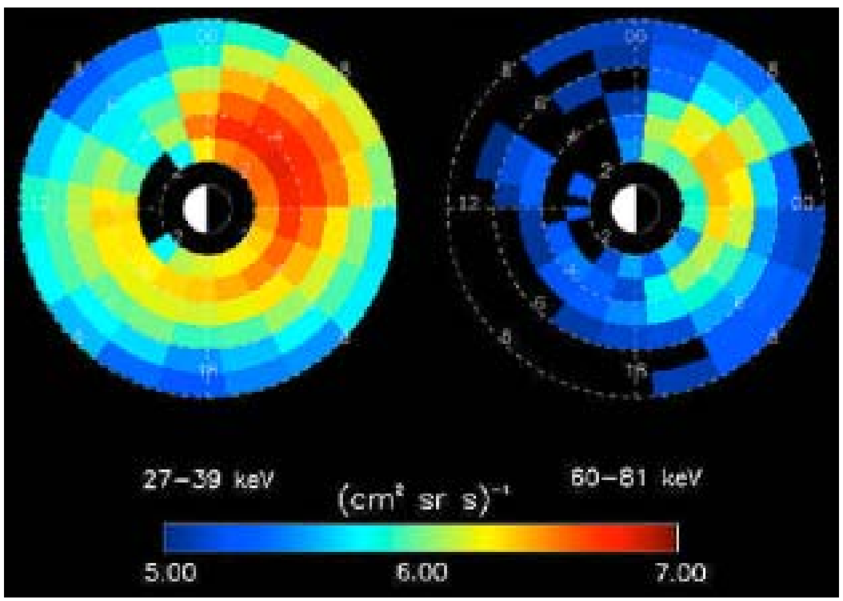
Geoelectric field pattern during storms differs from predictions of past models - electric fields deep in the inner magnetosphere exceed those at larger radial distances



Model

Fok et al., 2002

Ring Current Models Need Validation



ENA Image

Geospace Science Priority 2A

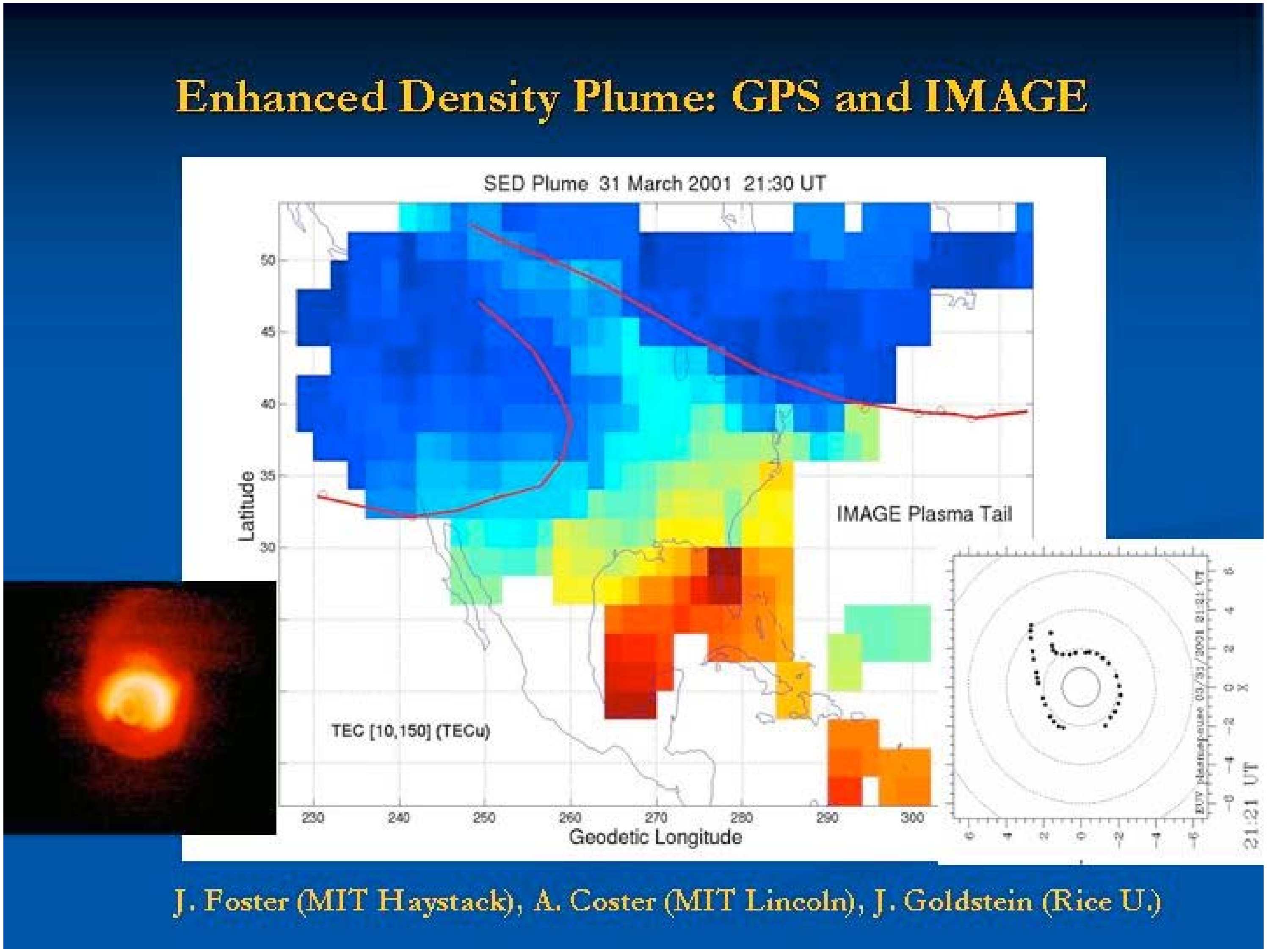
- **Determine the effects of long and short term variability of the Sun on the global-scale behavior of the ionospheric electron density.**
  - How does the I-T system vary in response to changing flux of solar EUV radiation?
  - How does the mid and low-latitude I-T system respond to geomagnetic storms?
  - How do negative-phase ionospheric storms develop, evolve, and recover?

- **Note overlap with priority 3A**
  - Determine the effects of solar and geospace variability on the atmosphere enabling an improved specification of the neutral density in the thermosphere.

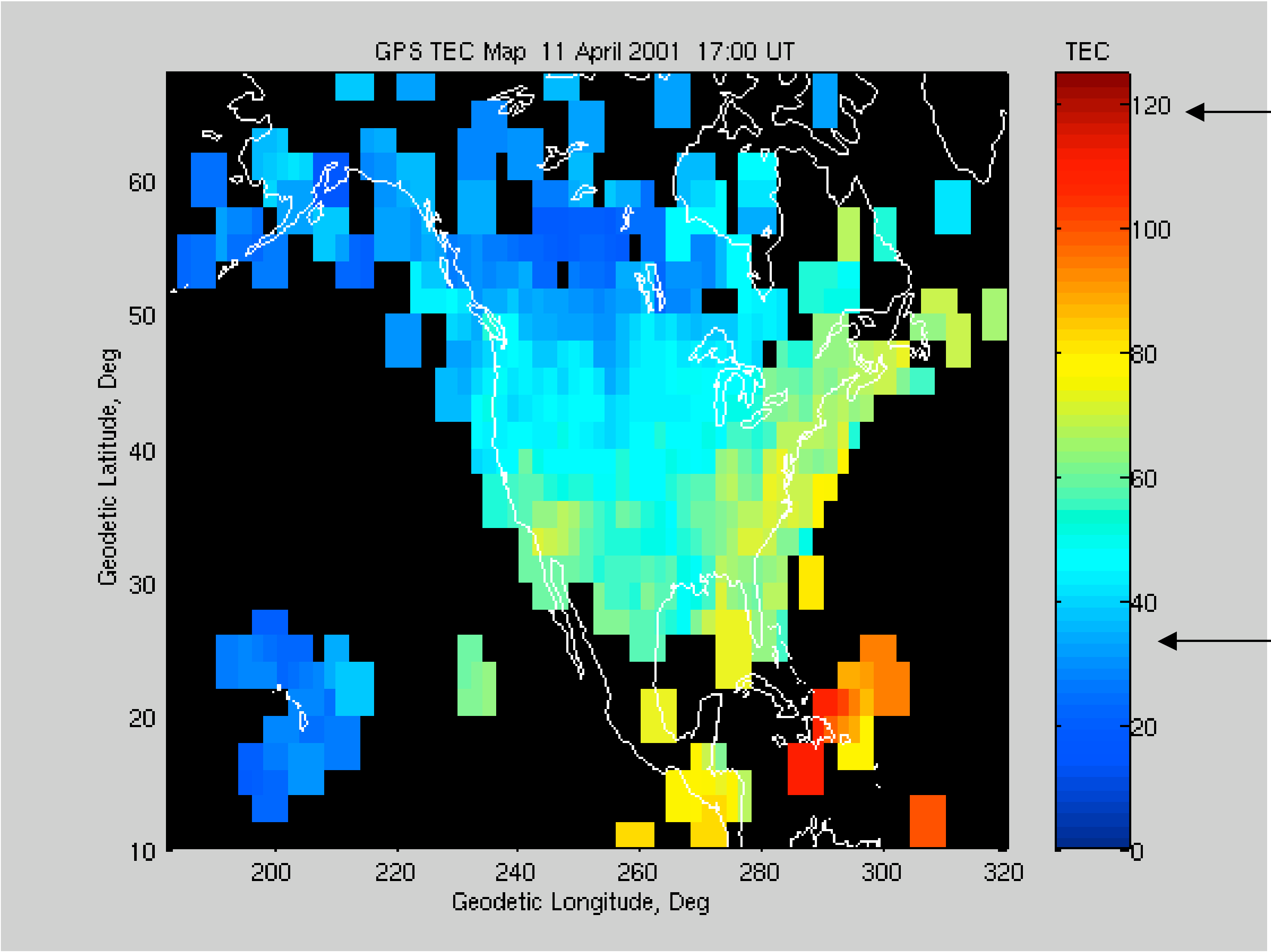
Geospace Science Priority 2B

- **Determine the solar and geospace causes of small scale ionospheric density irregularities in the 100 to 1000 km altitude range.**
  – What are the sources and characteristics of ionospheric irregularities at mid-latitudes?
  – What are the space weather effects of ionospheric variability at mid-latitudes?

Storm Enhanced Densities



Example of I-T Storm Positive Phase Evolution

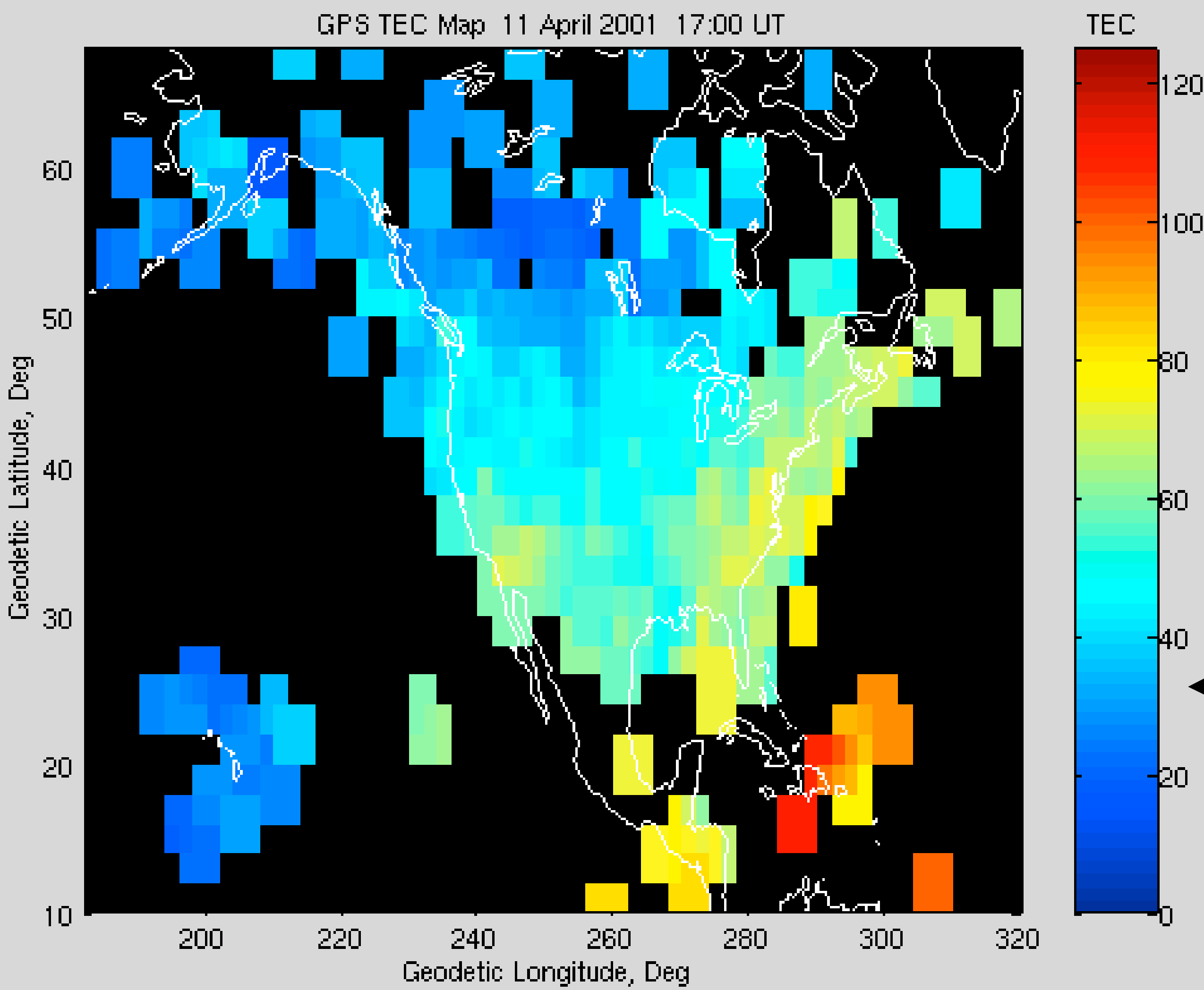


About 50 m of error

5 min cadence

Normal TEC

Example of I-T Storm Positive Phase Evolution

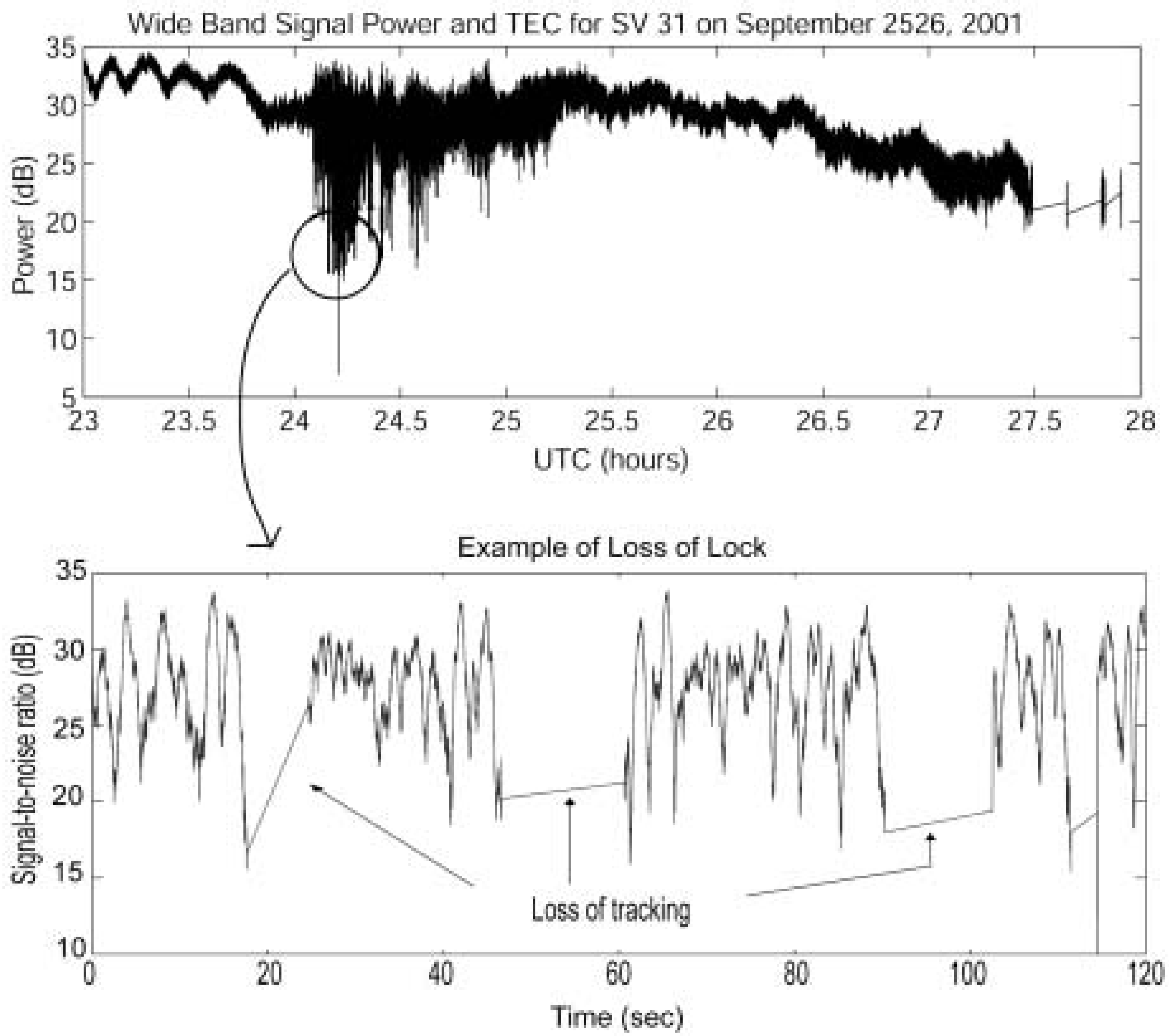


About 50 m of error

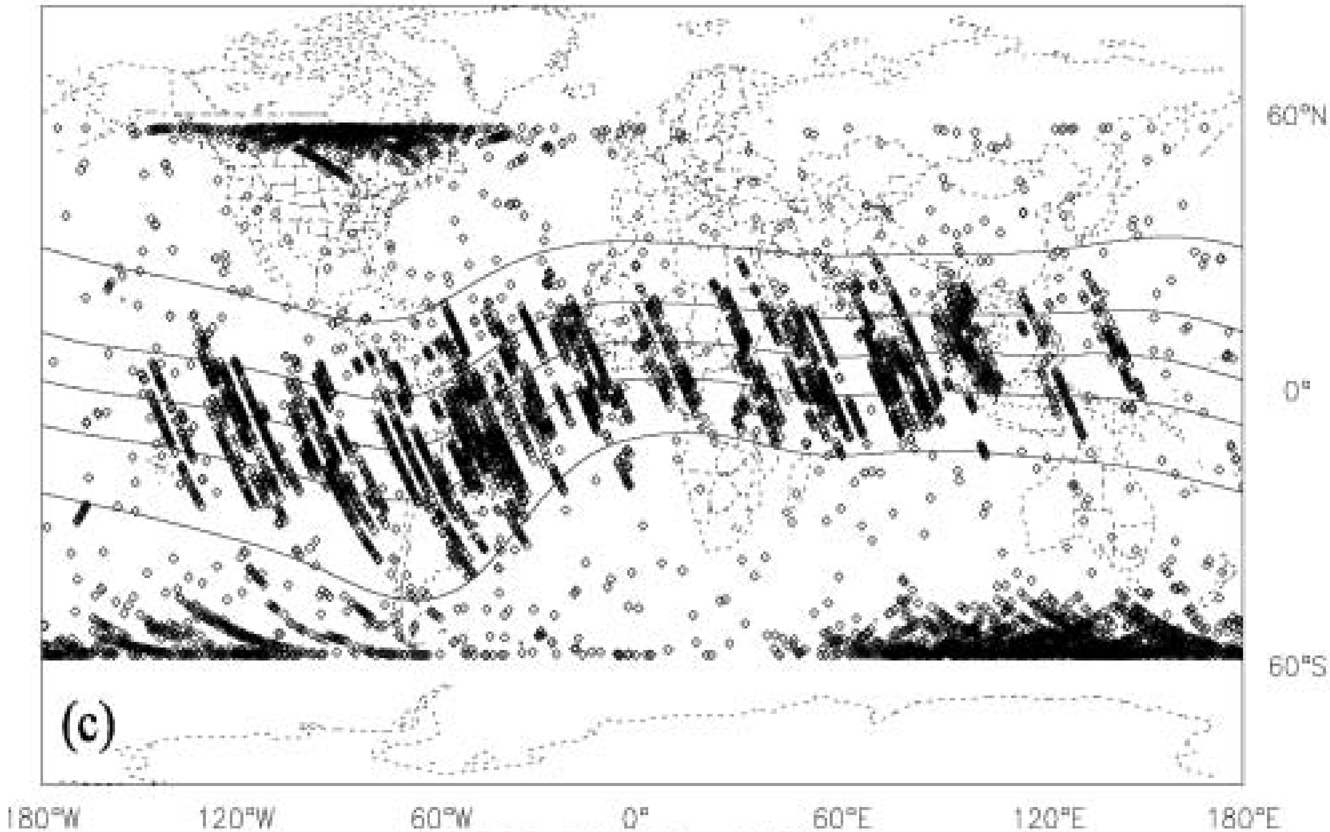
5 min cadence

Normal TEC

GPS Tracking Failure in Ithaca, NY



Scintillations Affect Shuttle



STS 99 2/11/00 to 2/22/00.

Delta-phase Range Data Derived from GPS that was "Profoundly Corrupt"

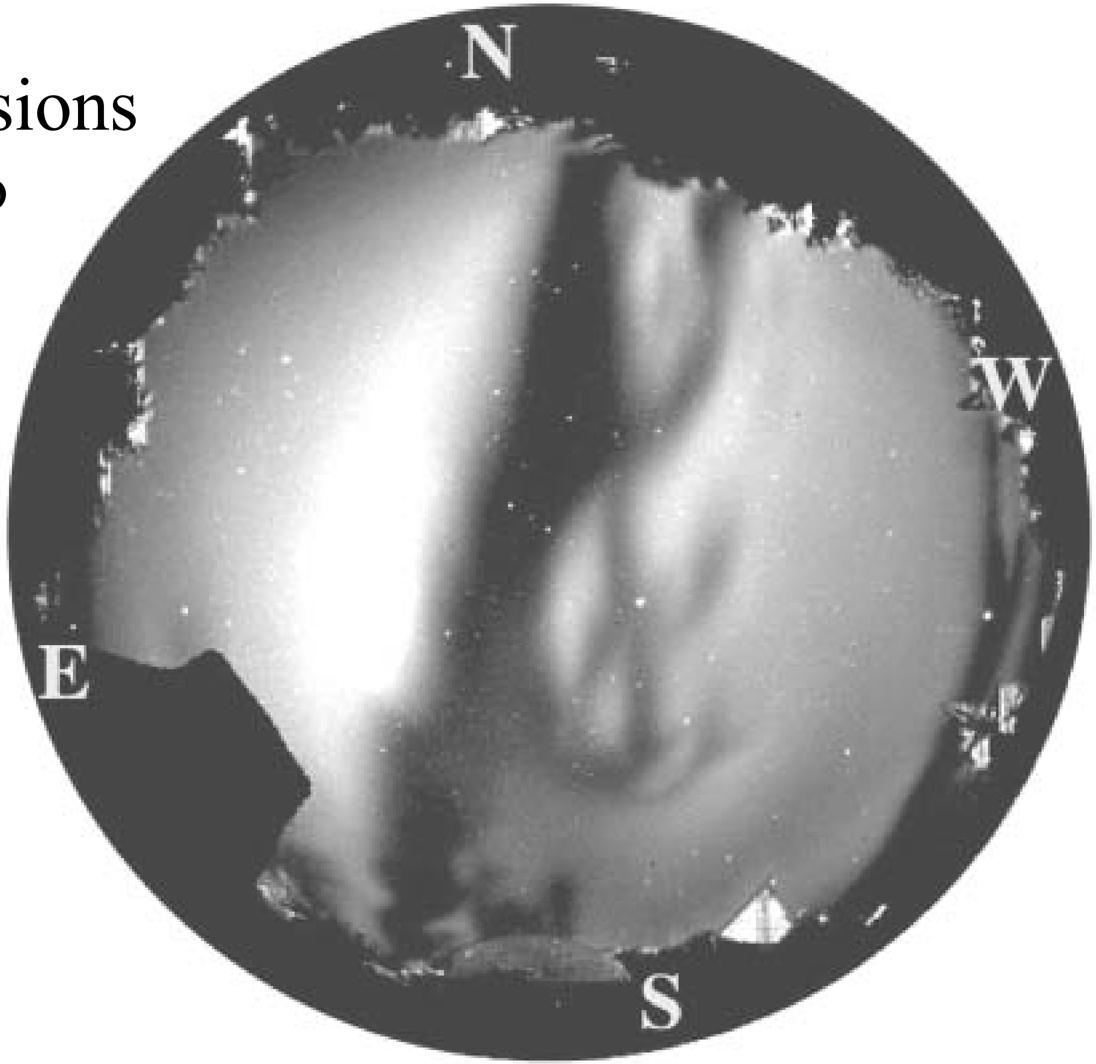
Kramer and Goodman, AIAA 2001

Storm Induced Ionospheric Holes at Mid-Latitudes

630nm Airglow Emissions

Arecibo, Puerto Rico

22 November 1997



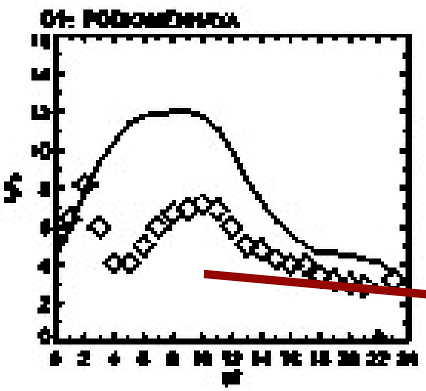
Kelley et al., 2000

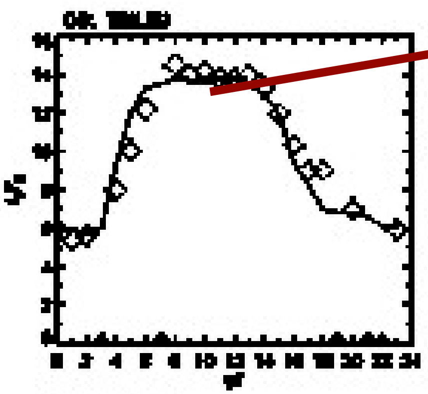
Negative Ionospheric Storm Tracks Region of Low O/N_2

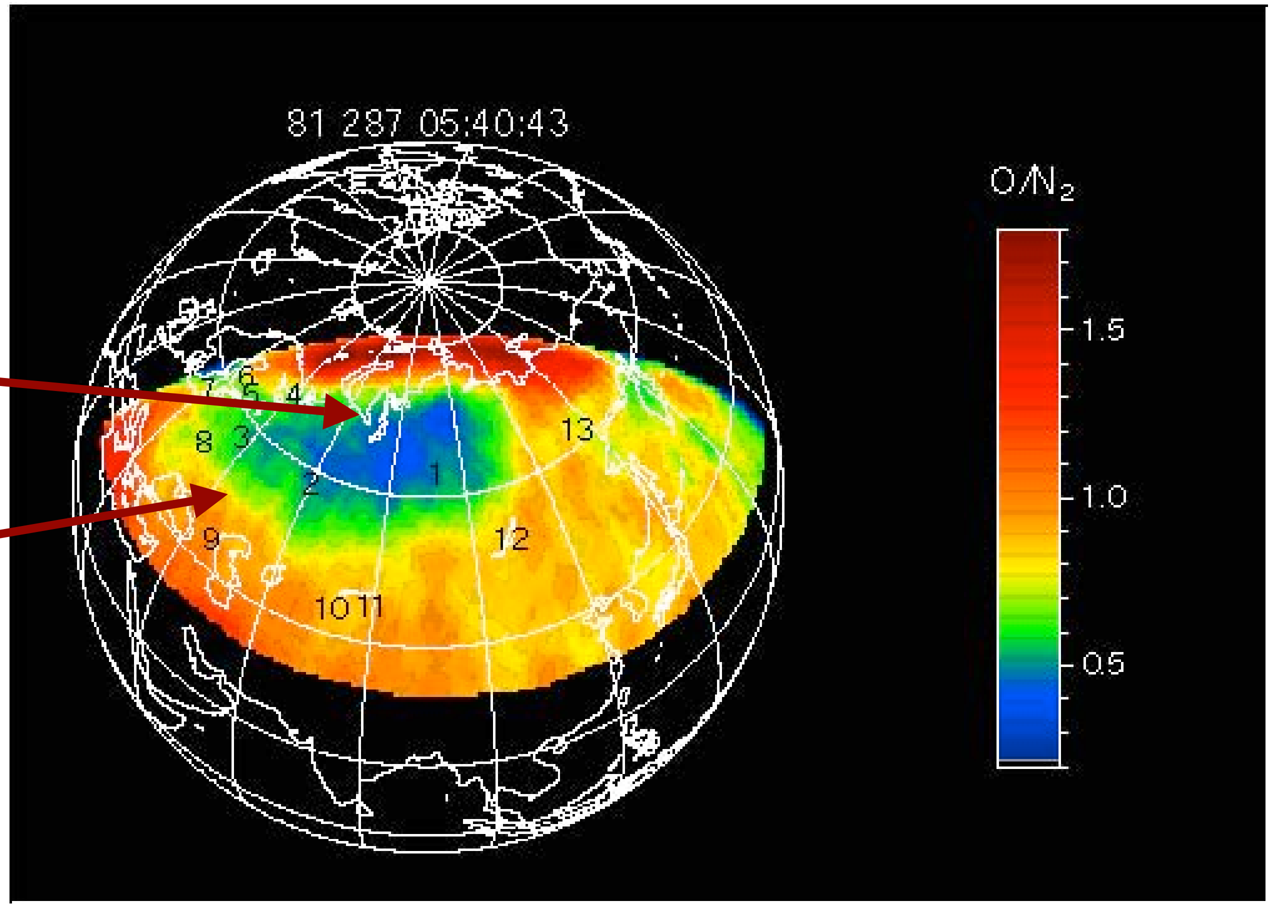
Ionosonde
24 hr data
14 Oct. 1981

Monthly Mean ———
Daily Data ◇◇◇

f_oF_2 follows O/N_2 inferred from DE-1 FUV image







Components of the LWS Geospace Project

Additional Flight Elements, forming the BASELINE	CORE Flight Elements	AUGMENTATIONS and NEWORK LEVEL Flight Elements

LWS Geospace Integration with Other Programs

Closure Through Geospace Modeling

LWS/Geospace Flight Elements

Barry Mauk

LWS Geospace Mission Scientist At Johns Hopkins University

Nicola Fox

LWS Geospace Study Scientist at JHU/APL

Traceability is Key to Development of the Geospace Implementation Plan

LWS/Geospace General Objective:	Specific Objectives:
Priority 1: Understand the acceleration, global distribution, and variability of energetic electrons and ions in the inner magnetosphere. SAT report: WG1-5 and 6, WG2-4	***Priority 1:*** ***1.1:*** **Differentiate among competing processes affecting the acceleration and transport of outer radiation belt electrons.**
	Priority 2: ***1.2a:*** **Differentiate among competing processes affecting precipitation and loss of outer radiation belt electrons.**
	1.2b: **Understand the creation and decay of new electron radiation belts.**
	1.2c: **Develop and validate physics-based data assimilation and specification models of outer radiation belt electrons.**
	Priority 3: ***1.3a:*** **Understand the role of "seed" or source populations for relativistic electron events.**
	1.3b: **Quantify the relative contribution of adiabatic and nonadiabatic processes on energetic electrons.**
	1.3c: **Understand the effects of the ring current and other storm phenomena on radiation belt electrons and ions.**
	Priority 4: ***1.4a:*** **Understand how and why the ring current and associated phenomena vary during storms.**
	1.4b **: Develop and validate physics-based and**

Radiation Belt Priority Observables

Priority Objective: Characterize and understand the acceleration, global distribution, and variability of the radiation belt electrons and ions that produce harsh environments for spacecraft and humans.

Which physical processes produce radiation belt enhancements?

- Direct convection
- Explosive inductive electric fields
- ULF waves and classical diffusion
- Interplanetary shocks.
- Local, invariant-violating acceleration processes

Measurements:

- Simultaneous particle intensities at various radial distant separations
- Simultaneous multi-point phase space densities (full pitch angles and **B**)
- Global convection/transient **E,** and **E** and **B** waves
- Simultaneous multipoint **B** for characterizing dynamic configuration
- Ring current ion composition and intensity

Radiation Belt Priority Observables

What are the dominant mechanisms for relativistic electron loss?

- Magnetopause shadowing.
- Current sheet scattering
- Plasma Wave scattering
- Coulomb scattering

Measurements:

- Electron pitch angle distributions near loss cone
- Low-altitude electron precipitation losses and compare with equator
- Power spectral intensity of relevant plasma waves

What role does the ring current play in radiation belt creation and loss?

- Time history, locus, composition, and energy of ring current ions
- Role of ring current in storm-time waves affecting radiation particles
- Role of the ring current on global electric and magnetic fields that cause radiation belt transport.

Measurements:

- In-situ ring current ion composition, pressure gradients
- Global distribution and evolution of ring current ion composition, energy density and pressure gradients

Ionosphere-Thermosphere Priority Observables

Priority Objective: Characterize and understand mid-latitude ionospheric variability and irregularities that affect communications, navigation and radar systems.

How does the I-T system vary in response to changing solar EUV?

- Solar EUV spectral irradiance
- In-situ I-T neutral composition, temperature, and winds
- In-situ plasma density and plasma density height profiles
- Global distributions of O/N_2 and Ne^2

How does the mid- and low-latitude I-T system respond to positive-phase storms?

- In-situ electric-fields/ion-drifts, neutral wind and composition, plasma density, and density-height profiles sampled simultaneously at adjacent longitudes.
- Role and evolution of penetrating polarization fields
- Role of magnetospheric inputs and fields on identified, in-situ parameters.
- Density gradient proxies for conductivity gradients and scintillation sources.
- Role of neutral winds on plasma transport and polarization fields.

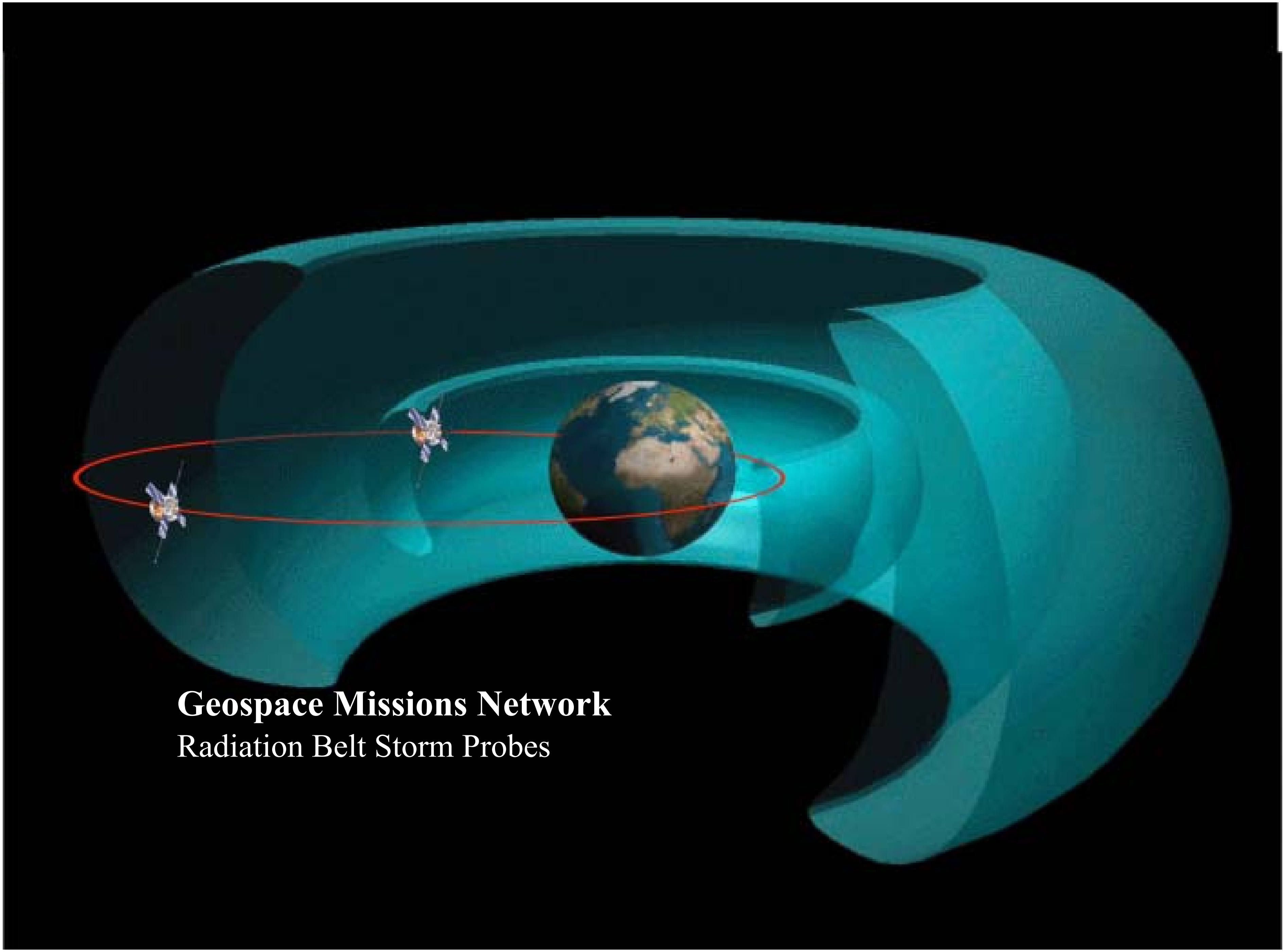
Ionosphere-Thermosphere Priority Observables

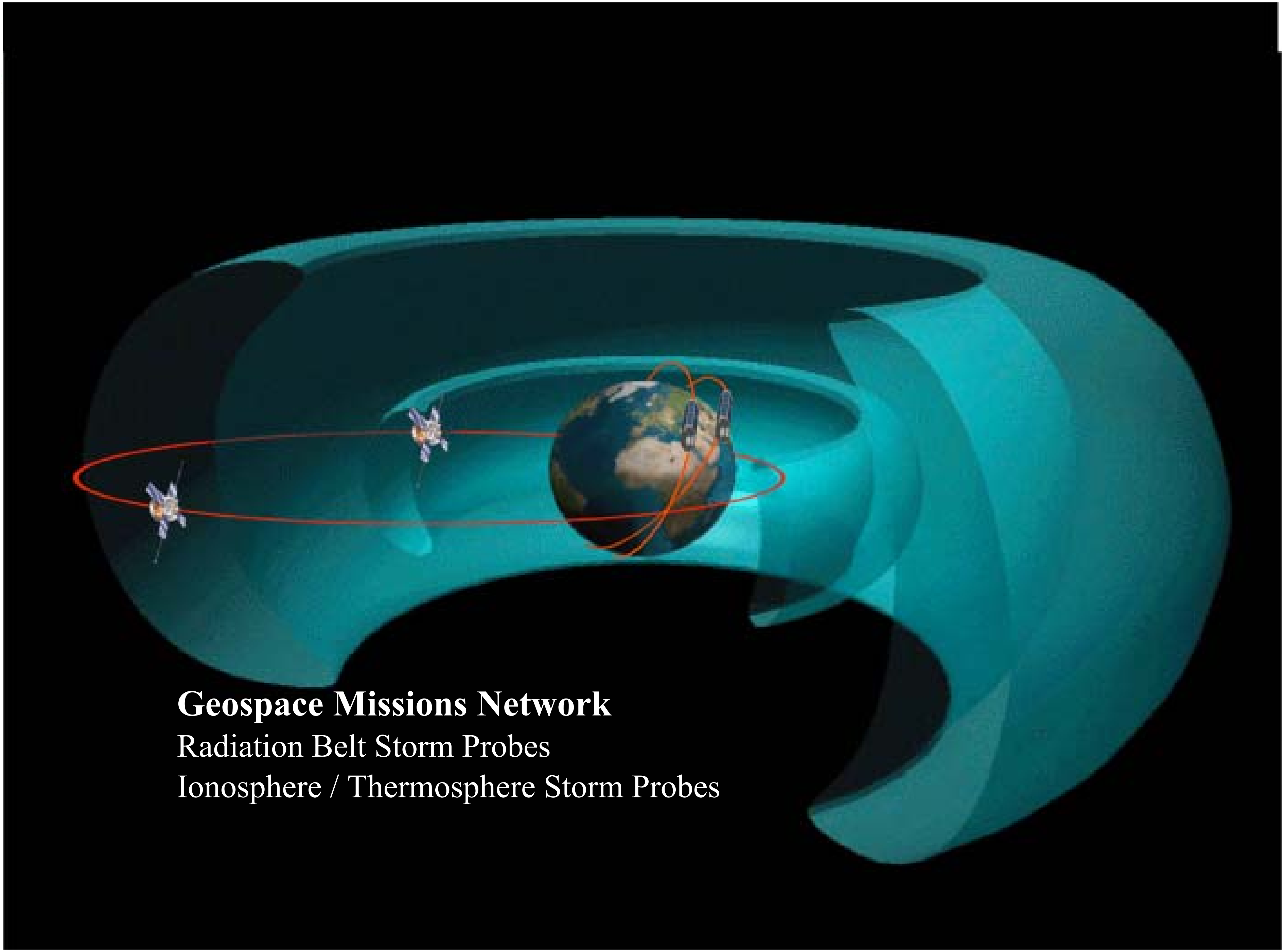
Negative-phase ionospheric storm development, evolution, & recovery

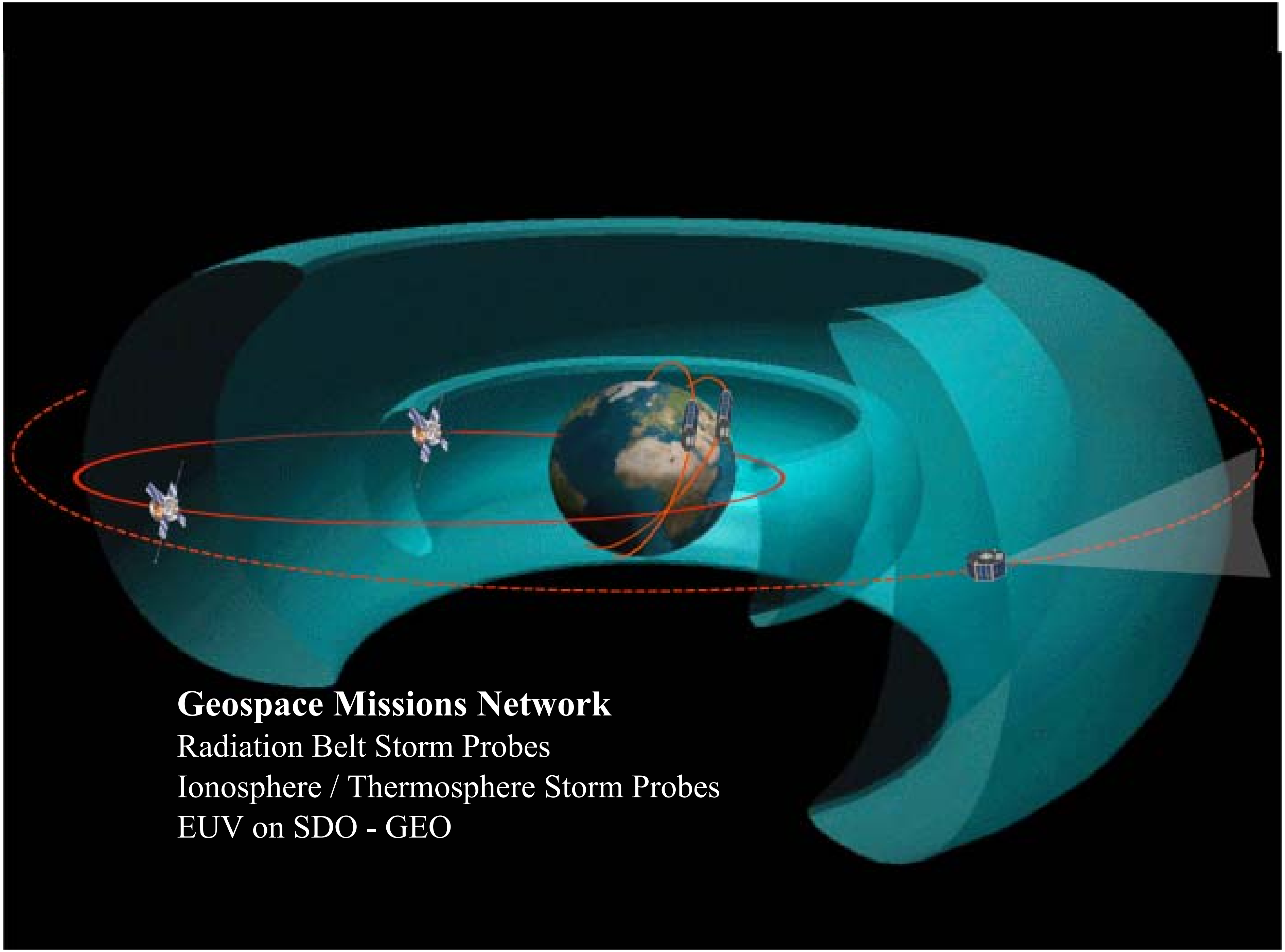
- Spatial structure and temporal evolution of Joule heating.
- Thermospheric winds over range of longitude separations.
- Temperature/composition response to neutral upwelling and downwelling.
- Extent and evolution of dayside O depletions
- Composition transport by winds
- Relationship between neutral composition structures and ion depletions.
- Neutral wind – electric field relationship.
- Importance of dynamo processes in plasma transport
- Role of latitude-longitude thermal structure in global circulation

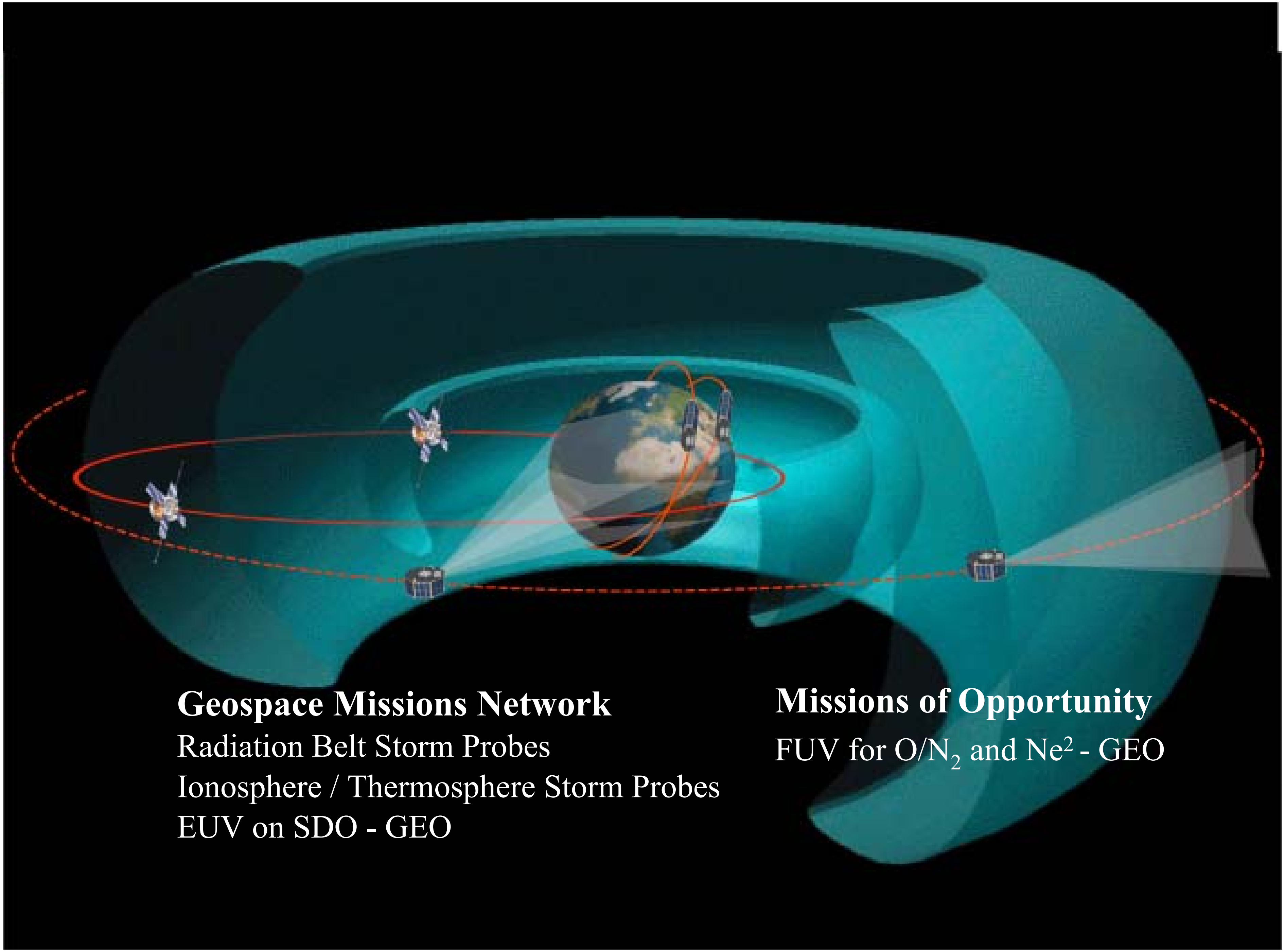
Sources and characteristics of mid-latitude ionospheric irregularities

- Extend, morphology, amplitudes of mid-latitude irregularities
- Discover free-energy sources
- Spectral properties that produce scintillations
- Determine detailed electric field/density wave characteristics of irregularities


Geospace Missions Network
Radiation Belt Storm Probes


Geospace Missions Network
Radiation Belt Storm Probes
Ionosphere / Thermosphere Storm Probes


Geospace Missions Network
Radiation Belt Storm Probes
Ionosphere / Thermosphere Storm Probes
EUV on SDO - GEO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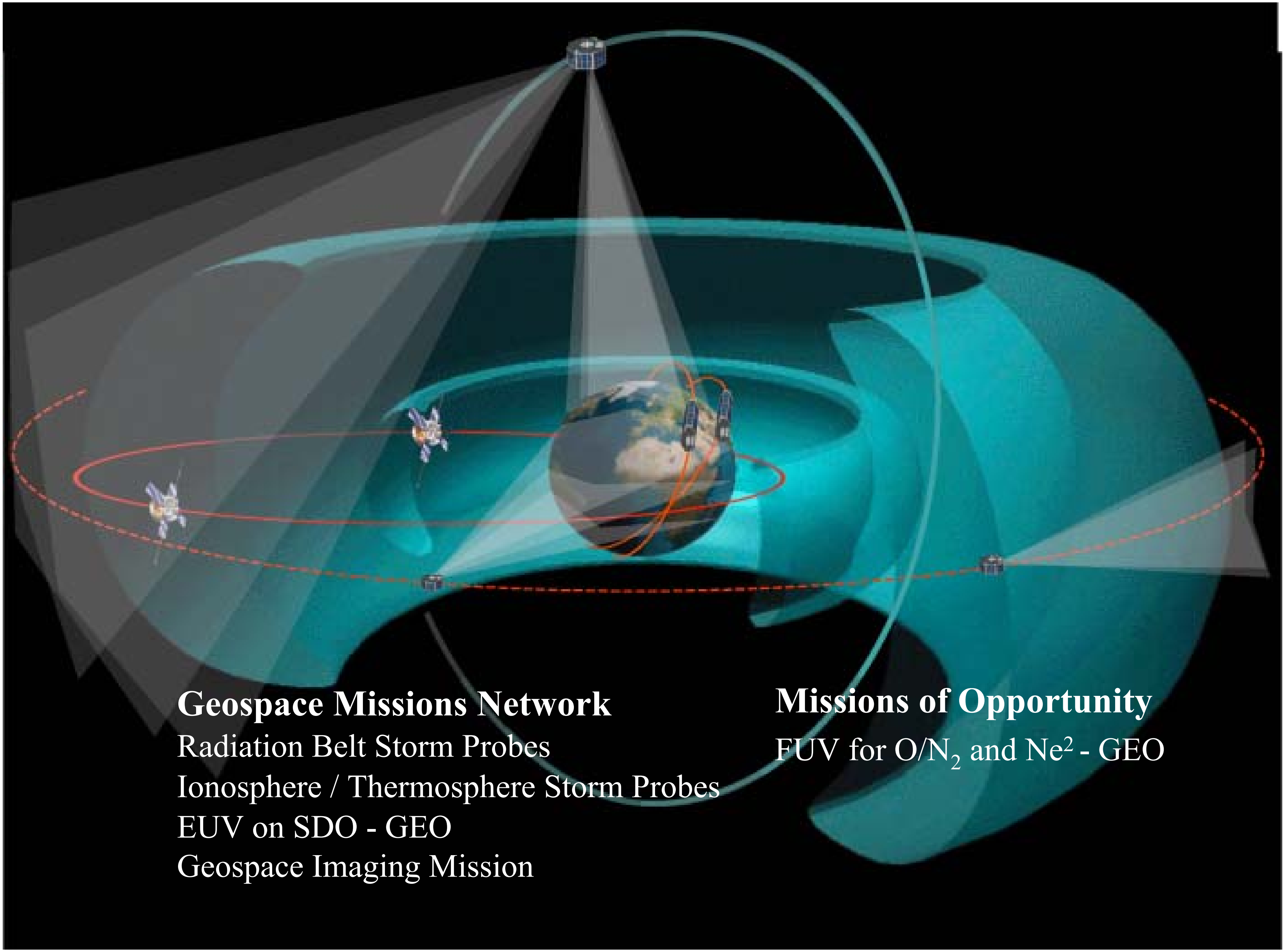
Missions of Opportunity
FUV for O/N_2 and Ne^2 - GEO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Overview of Radiation Belt Storm Probes

Description: Main spacecraft and trailing smaller spacecraft in near equatorial, elliptical orbits (~500 km x 4.5 R_E altitude)

Mission Life: 2 years with optional 3-yr extension

Launch Date: 2010

Space Access: One launch on Medium Class ELV

Measurements, main spacecraft:

- 20 keV - 20 MeV electrons
- **B** and ULF waves
- DC E-field
- B and E VLF waves
- ring current ions (20-600keV), composition
- **plus, if feasible,**
  - energetic protons (1-200 MeV)
  - 0.01 – 20 keV ions and electrons

Measurements, smaller spacecraft:

- 20 keV - 1 MeV electrons
- **B** and ULF waves
- ring current ions (20-600keV), composition

plus, if feasible,

- ENA ring current imager on appropriate polar, high altitude, spacecraft
- and, on platform in LEO orbit,
  - precipitating energetic electrons (20 keV – 20 MeV)
  - proton monitor (1-200 MeV)

Overview of Ionosphere-Thermosphere Storm Probes

Description: Twin ionospheric spacecraft at 60° inclination, 450 km altitude circular orbits, separated by 10° - 20° longitude

Mission Life: 3 years with optional 2-yr extension

Launch Date: 2008

Space Access: One launch on Medium Class ELV

Measurements, both spacecraft:

- plasma density, drift, and density fluctuations
- thermospheric wind, density and composition
- ionospheric (Ne) altitude profiles
- in-orbit scintillations

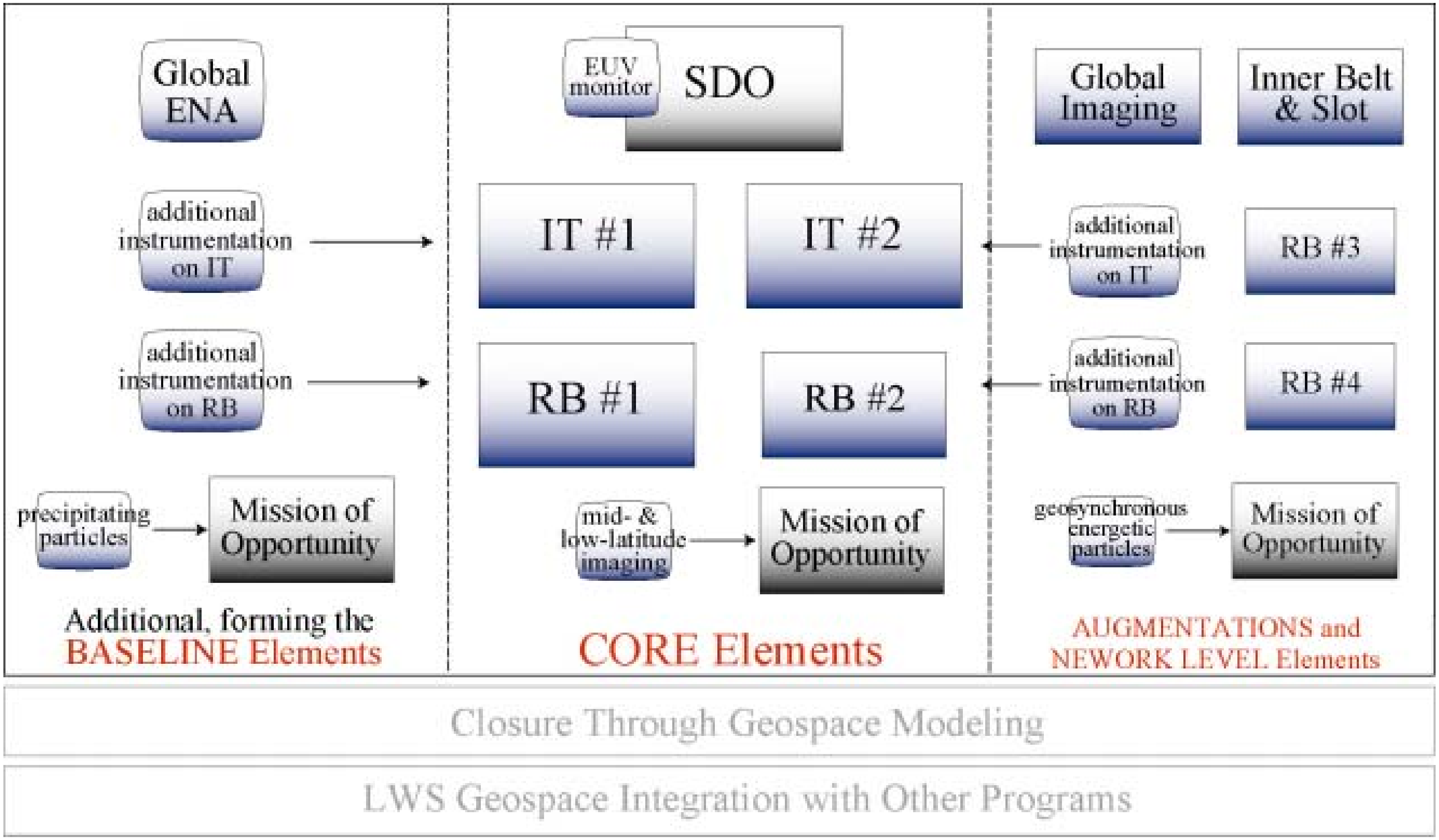
including,

- EUV spectral flux on LWS Solar Dynamics Observatory spacecraft,
- I-T mid-latitude imager package at GEO: FUV for O/N_2 and Ne^2

plus, if feasible,

- Auroral electron precipitation
- Currents (**B**)
- AC electric fields

The Geospace Science Investigations



The Broader Geospace Program and Opportunities for Participation

Barbara Giles

LWS Geospace Project Scientist

NASA Goddard Space Flight Center

How do the program flight elements address the objectives?

CORE
Flight Elements

Additional Flight Elements, forming the BASELINE

AUGMENTATIONS and NEWORK LEVEL Flight Elements

Integration with Other Programs

Closure Through Geospace Modeling

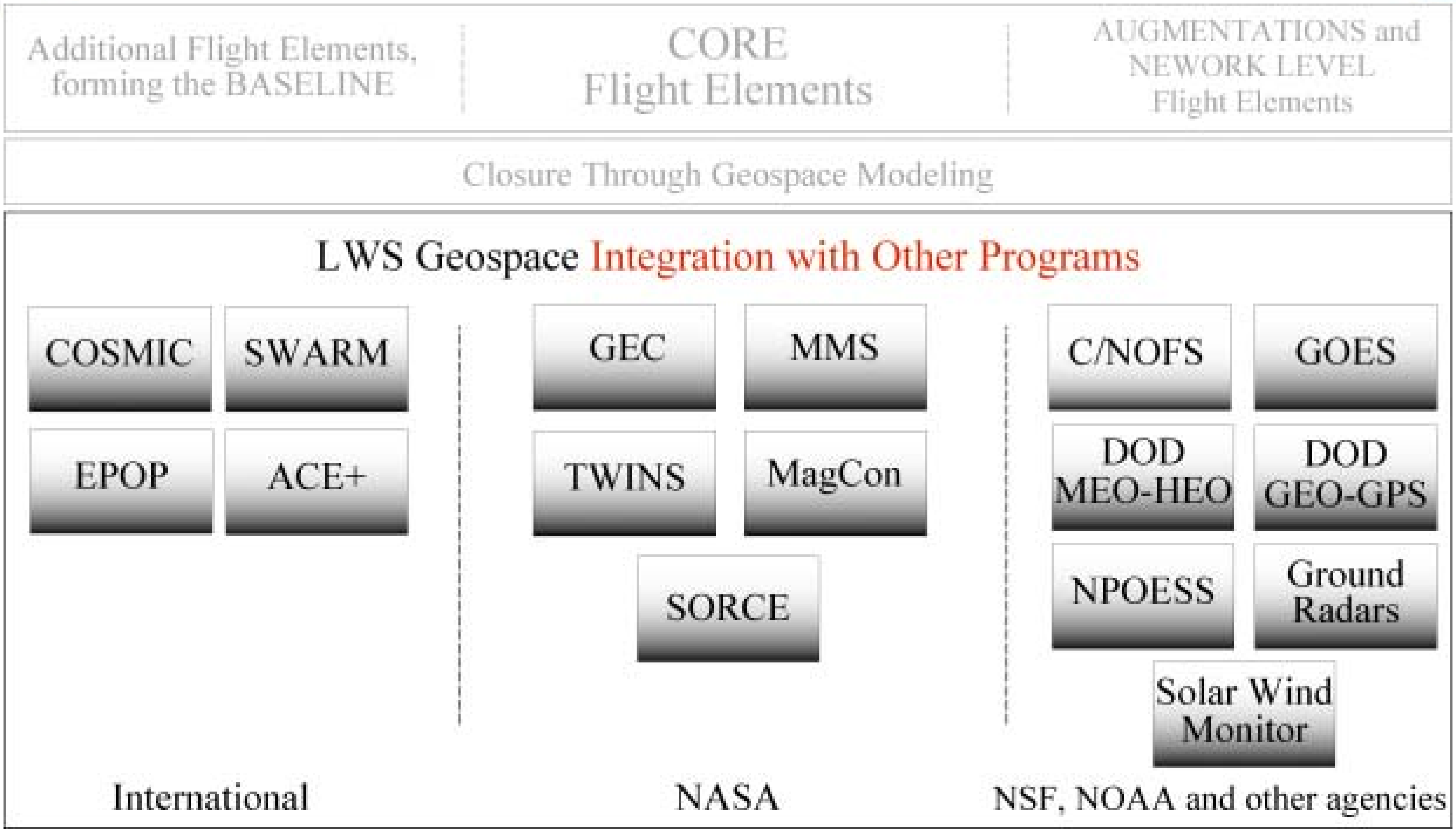
Characterize and understand:

- acceleration, global distribution, and variability of the radiation belt electrons and ions;
- mid-latitude ionospheric variability and irregularities.

Essential to address the full range of science objectives:

- IT & RB measurements not within the scope of the planned flight elements;
- characterizing extremes of variability outside the epoch of Geospace Missions;
- planned measurements that cannot be accommodated within flight budget;

Integration with Other Programs to form a Single Observing Resource



Data from non-LWS spacecraft before, during and following the LWS flight phase, if coordinated and combined with LWS to **form a single observing resource**, will maximize our understanding and characterization of the Geospace systems.

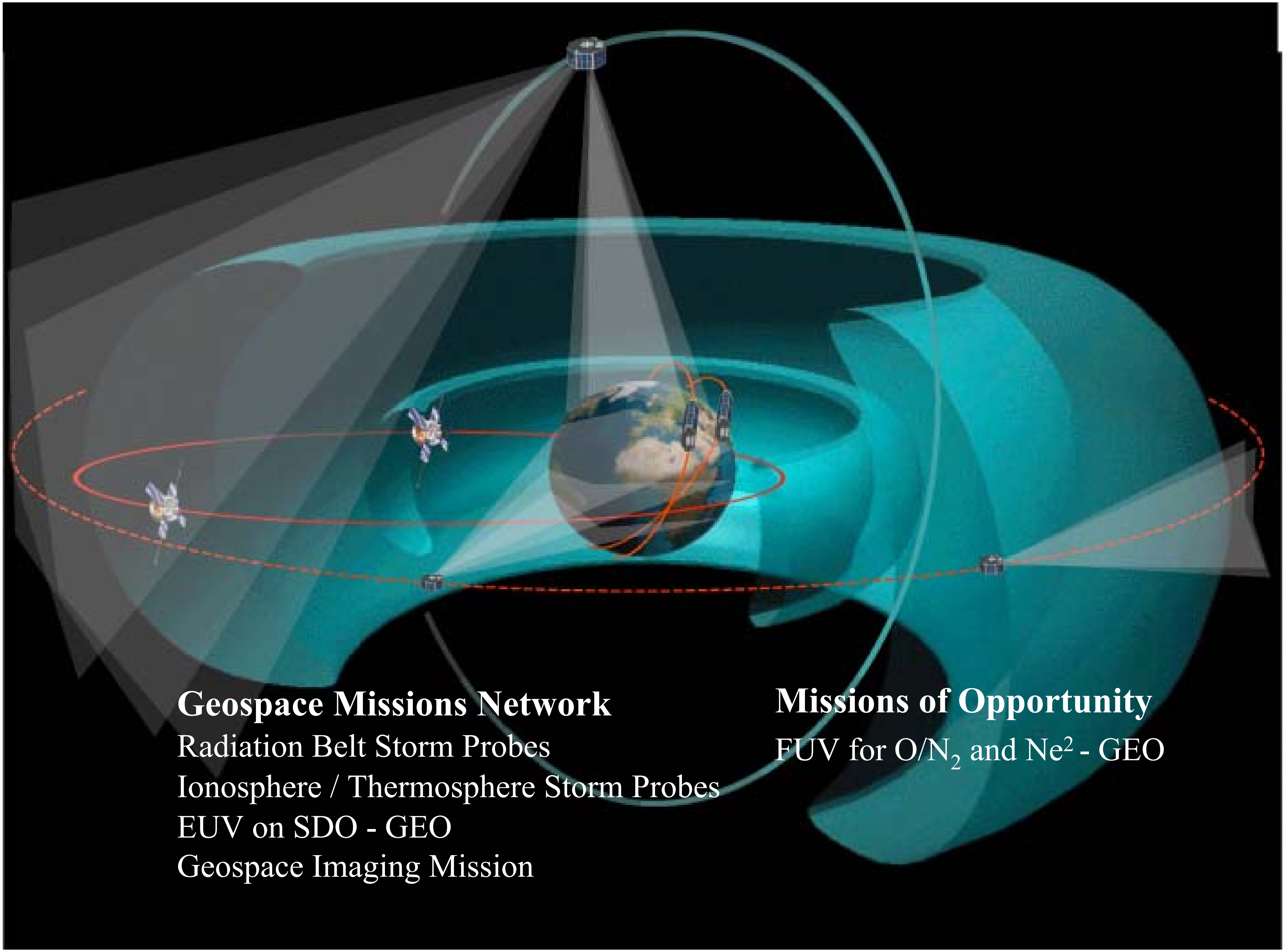
Priority Measurements From Other Programs

Essential measurements for addressing the full range of LWS/Geospace Science Objectives:

- solar wind parameters;
- high-latitude magnetospheric energy input to the I-T system during storms
- magnetospheric seed populations for the high-energy electron radiation belts
- global electric and magnetic field topology
- global distribution of ULF waves
- low-latitude ionospheric irregularities

Complementary measurements, especially useful to characterize extremes of variability outside the epoch of Geospace Missions:

- radiation belt particle and seed population measurements;
- high-latitude ionospheric irregularities
- solar energetic particles


Geospace Missions Network
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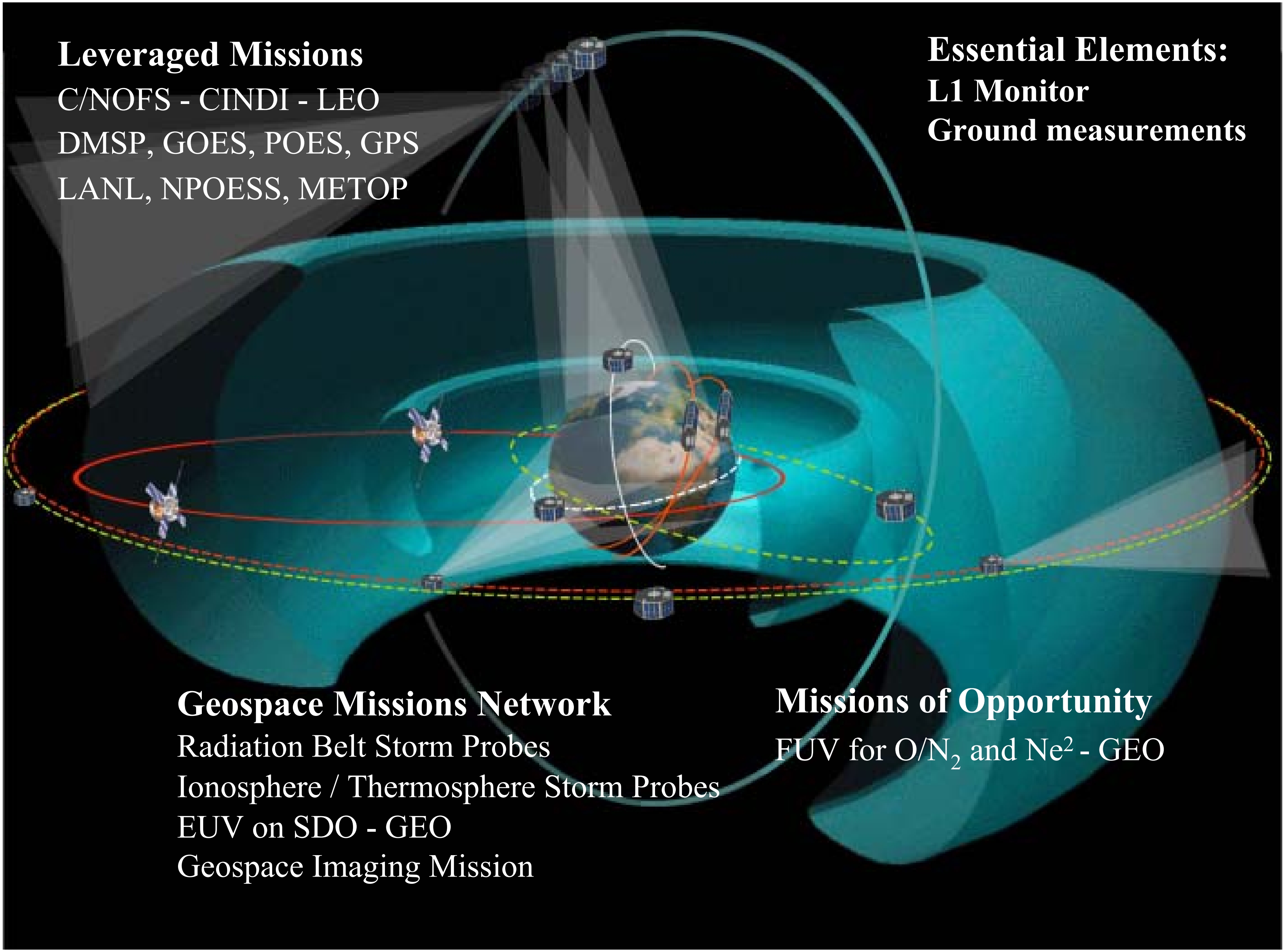
Geospace Imaging Mission
Missions of Opportunity
FUV for O/N_2 and Ne^2 - GEO


Leveraged Missions
C/NOFS - CINDI - LEO
DMSP, GOES, POES, GPS
LANL, NPOESS, METOP
Essential Elements:
L1 Monitor
Ground measurements
Geospace Missions Network
Radiation Belt Storm Probes
Ionosphere / Thermosphere Storm Probes
EUV on SDO - GEO
Geospace Imaging Mission
Missions of Opportunity
FUV for O/N$_2$ and Ne^2 - GEO

Closure through Theory and Modeling

Additional Flight Elements, forming the BASELINE	CORE Flight Elements	AUGMENTATIONS and NEWORK LEVEL Flight Elements

LWS Geospace Integration with Other Programs

Closure through Theory, Modeling and Simulation

Geospace Flight Program Theory and Modeling	LWS Program Targeted Research and Technology
Obtaining science understanding and enabling model development	Testing science understanding and prototyping space weather models for the user community

Geospace Flight Program
Theory and Modeling

Model development and utilization as an integral part of an IT or RB science investigation,

such as:

- determining the relative importance of the convective transport of energetic particles by improving models of global electric fields;
- apply statistical correlations to ascribe the proportion of ionospheric variability attributable to the EUV source and/or spectral changes.

that are needed

- for unifying data sets from disparate sources;
- as a substitution when data is unattainable;
- for providing a framework for interpreting observational data;
- to provide understanding of underlying physical mechanisms.

LWS Targeted Research and Technology

Develop and upgrade first-principal, empirical, and data assimilation models to incorporate improved understanding of the radiation belts, ionosphere/thermosphere systems, and the coupled Geospace environment.

This will lead to:

- dynamic specification of the two regions over a solar cycle;
- improved real-time description of the space environment (nowcasting);
- prediction of the environment (forecasting).

that are needed:

- for engineering design purposes and for mission planning;
- to build the next generation of space weather models.

Opportunities for Participation

Yearly Research Opportunities:

- ROSS NRA solicitations for Targeted Research & Technology
- SEC Instrument Development solicitation in 2003

For the Flight Program:

- release of AO for Ionosphere-Thermosphere Storm Probes in 2003;
- AO for Radiation Belt Storm Probes to follow thereafter.

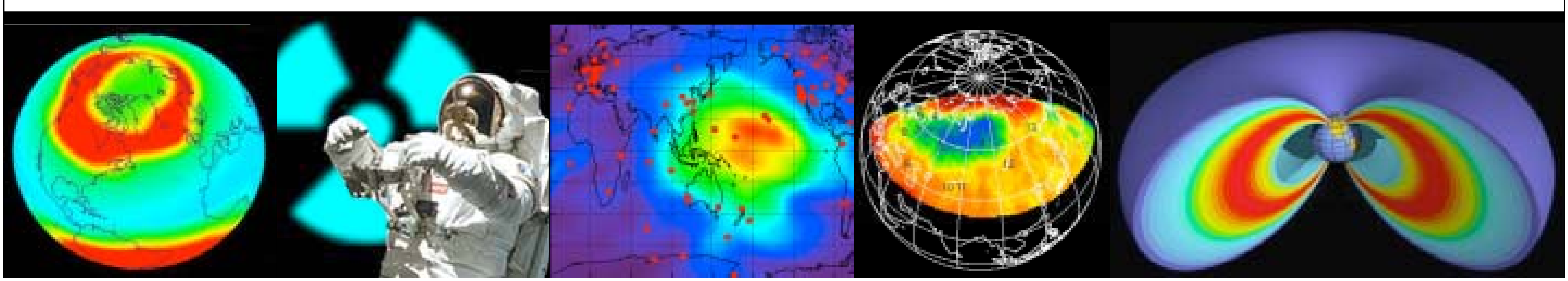
Other possible opportunities not yet defined:

We invite questions and further discussion on any aspect of the LWS Geospace science objectives, observation requirements, or flight program:

- Madhulika Gurhathakurta / 202-358-1992 / mguhatha@mail.hq.nasa.gov
- Paul Kintner / 607-255-3989 / pmk1@cornell.edu
- Barbara Giles/ 301-286-0447 / barbara.l.giles@nasa.gov
- Barry Mauk / 240-228-6023 /barry_mauk@jhuapl.edu
- Nicola Fox / 240 228 3529 / nicola.fox@jhuapl.edu

LWS/Geospace: Science in the Pasteur Mode

		for Utility	
		No	Yes
for Understanding	Yes	Bohr	Pasteur
	No		Edison



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